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A

MANUAL OF CHEMISTRY;

CONTAINING

THE PRINCIPAL FACTS OF THE SCIENCE, ARRANGED IN THE ORDER IN
WHICH THEY ARE DISCUSSED AND ILLUSTRATED IN THE
LECTURES AT THE ROYAL INSTITUTION OF
GREAT BRITAIN.

BY

WILLIAM THOMAS BRANDE,

Secretary of the Royal Society of London; Fellow of the Royal Society of Edinburgh; Member of,
and Professor of Chemistry in the Royal Institution of Great Britain; Professor of Chemistry
and Materia Medica to the Society of Apothecaries of the City of London; Member
of the Geological Society of London; Honorary Member of the Literary
and Philosophical Society of New-York; of the Physico-Medical
Society of Erlangen: and of the Pharmaceutical
Society of Petersburgh.

THE FIRST AMERICAN,
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Three Volumes in One.

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NOTES AND EMENDATIONS:

BY

WILLIAM JAMES MACNEVEN, M.D.

Professor of Chemistry in the College of Physicians and Surgeons of the
University of the State of New-York, and Member of
the Literary and Philosophical Society.

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BE IT REMEMBERED, That on the fourteenth day of November, in the forty-sixth year of the Independence of the United States of America, *George Long*, of the said district, hath deposited in this office the title of a book, the right whereof he claims as proprietor, in the words following, to wit:

"A Manual of Chemistry; containing the principal facts of the Science arranged in the order in which they are discussed and illustrated in the Lectures at the Royal Institution of Great Britain. By William Thomas Brande, Secretary of the Royal Society of London: Fellow of the Royal Society of Edinburgh: Member and Professor of Chemistry in the Royal Institution of Great Britain: Professor of Chemistry and Materia Medica to the Society of Apothecaries of the City of London: Member of the Geological Society of London: Honorary Member of the Literary and Philosophical Society of New-York: of the Physico-Medical Society of Erlangen: and of the Pharmaceutical Society of Petersburgh.—The first American from the Second London Edition.—Three Volumes in one. To which are added Notes and Emendations, by William James Macneven, MD. Professor of Chemistry in the College of Physicians and Surgeons of the University of the State of New-York, and Member of the Literary and Philosophical Society.

In conformity to the act of the Congress of the United States, entitled, "An act for the encouragement of learning, by securing the copies of maps, charts, and books, to the authors and proprietors of such copies, during the time therein mentioned." And also to an act, entitled, "An act, supplementary to an act, entitled, An act for the encouragement of learning, by securing the copies of maps, charts, and books, to the authors and proprietors of such copies, during the times therein mentioned, and extending the benefits thereof to the arts of designing, engraving, and etching historical and other prints."

JAMES DILL,

Clerk of the Southern District of New-York.

ADVERTISEMENT.

A class book that should comprehend in regular order, the text of what is delivered in lectures, and what is expected from the candidate at examination, is a thing altogether so desirable for Professor and Student, that I had contemplated the compilation of such a work for the use of my pupils in this University, when, very opportunely, I received Mr. Brande's Manual. Having perused this well arranged outline of a course of Chemistry, I deemed my projected undertaking unnecessary: and yet, I could not adopt his book, nor recommend it to my class entirely in the shape he gives it. The atomic theory, as delivered by him, differs considerably from the view I take of it; and, as I hold this to be the exceptionable part of Mr. Brande's otherwise excellent performance, it only remained for me to change, or as I would fain say, amend it, in that particular. It is easily seen that his specific gravities and atomic weights are frequently inaccurate: nor is the error, perhaps, entirely accidental. Representative numbers recently determined in a very satisfactory manner are still given by Mr. Brande as they were represented five or six years ago, although Dr. Prout, but more especially Dr. Thomson has demonstrated that they required correction. The latter has clearly proved that the atoms of the simple bodies nitrogen, oxygen, chlorine, carbon, sulphur, phosphorus, iodine, are even multiples of the weight of an atom of hydrogen. He has also shown that when hydrogen is made the unity of weight, and oxygen the unity of specific gravity, then the weight of the atom of a gaseous body is either equal to the specific gravity, or some multiple of the same by a whole number.

If the specific gravity of oxygen be 1, that of hydrogen will be 0.0625, which × by 2 = 0.125, weight of the atom of hydrogen. In most cases of this kind the atomic weight is double the specific gravity; in a few, however, twice 2 is found to be the proper multiplier: the reason of this difference is not very obvious; but in the first the combination is most energetic. See the table added, p. 161.

In consequence of these views, the representative numbers for the elementary and compound atoms, throughout the whole work, have been altered to correspond with the results of the latest discoveries and improvements. Almost all the notes, likewise, are additions; In other respects, and wherever the investigations of Mr. Brande himself are given as authority, the text has suffered no change. But intending the manual only for a class book and text of my lectures, 188 pages of preface have been left out and 102 pages of index abridged to two. The first, though well composed, could, in this instance, be the better spared, as it is but an enlarged, though in several particulars, an improved version of the author's earlier dissertation on the progress of chemical science, of which an edition from the Boston press must be already known to the American reader. A wish to avoid making the publication too voluminous to be read in connexion with other studies, or rendering the price too high for beginners, induced me to retrench what was, in some measure, unnecessary; and, applying to myself the same rule, I forbear to lengthen this advertisement.

New-York, Nov. 20, 1821.

PREFACE.

Though the following pages are chiefly intended for students, it is trusted that the proficient will find them a useful compendium of Chemistry.

The arrangement of the materials differs from that sanctioned by our best elementary writers, but it has been adopted in consequence of some years' experience of its advantages in teaching the principles of the science.

In the first chapter, the leading facts connected with the general laws of chemical changes are discussed under the separate heads of Attraction, Heat, and Electricity. The second chapter relates to the properties of Radiant Matter, and its influence upon the composition of bodies. In the third and fourth chapters I have detailed the sources and properties of the Simple Supporters of Combustion, and of the Elementary Acidifiable Substances, and their mutual combinations. The fifth chapter contains an account of the Metals, and of their compounds with the bodies previously described, and with each other.

The sixth chapter embraces such details respecting the Assay and Analysis of Metalliferous Compounds, as are necessarily omitted under the individual history of the metals: in this division of the book I have availed myself largely of the invaluable analytical labours of Klaproth, and have selected from other sources such instances as I conceived best adapted to assist the student in acquiring correct notions of this department of chemical study; the processes detailed have, with few exceptions, been submitted to the test of experimental repetition in the laboratory of the Royal Institution, and those which have not been thus verified, are drawn from sources of the highest authority.

In the seventh chapter I have aimed at a succinct description of the means of analyzing mineral waters, and as their examination is frequently desirable where the conveniences of a regular laboratory are not attainable, I have subjoined a short account of the tests and apparatus required in this branch of research.

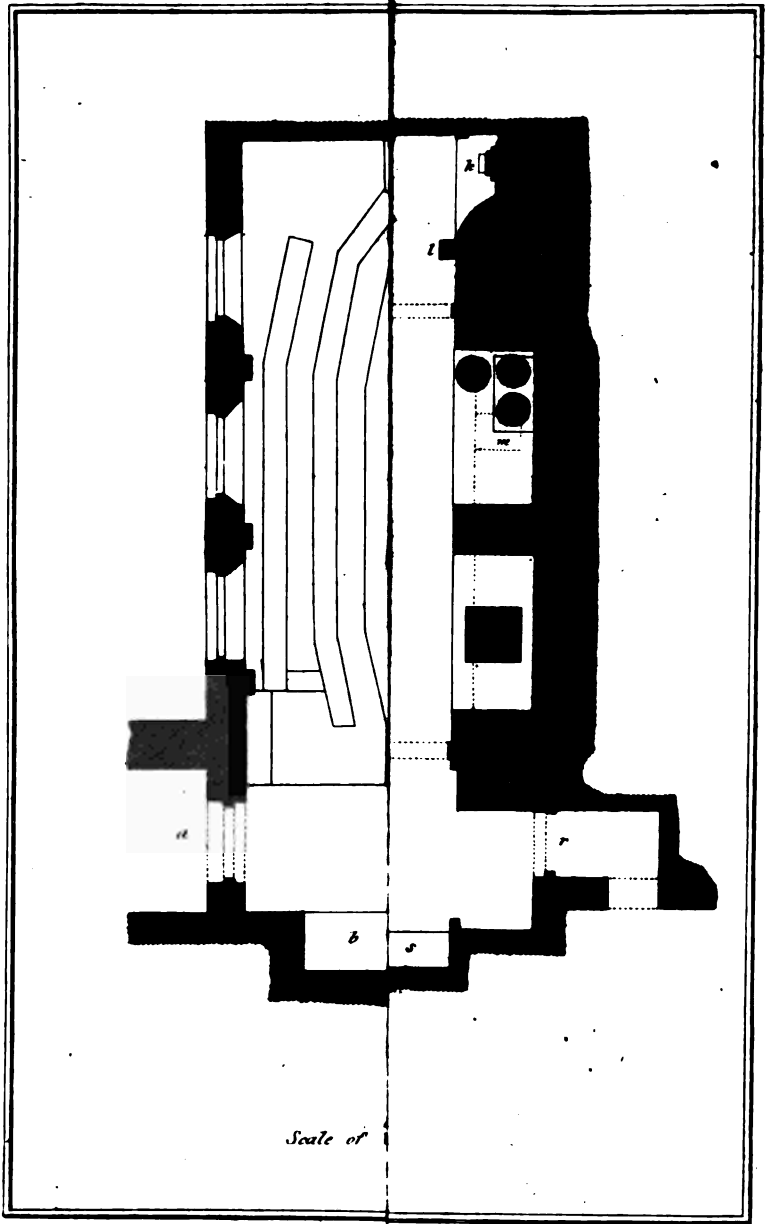
Upon the subject of analysis in general, the student will find inexhaustible information in the writings of Klaproth, and in the Essays of Vauquelin; the former have only been in part translated into the English language; and the latter are scattered through various periodical publications, especially the *Journal des Mines*, and the *Annales de Chimie.* The last thirty volumes of the *Philosophical Transactions* are also rich in detached essays, by our most eminent chemists, illustrative of the art of analysis. A judicious selection from these sources upon an extended scale would be truly valuable to the practical chemist, and would materially contribute to facilitate the progress of our analytical inquiries.

For general directions concerning the art of analysis, and for many useful and original hints relative to the manipulations of the laboratory, I have much satisfaction in referring to Mr. Children's translation of the fourth volume of M. Thenard's *Traite de Chimie.* The reader will observe, that in Chapter VI. I have availed myself of this work, which the student will do well to consult in detail.

The eighth and ninth chapters are assigned to Vegetable and Animal Products; and the concluding chapter contains the heads of Geological inquiry.

In the Appendix to this work will be found Tables, chiefly useful as presenting a synoptic view of most of the simple and compound bodies, with their representative or equivalent numbers; these may easily be transferred to a logometric scale, as recommended by Dr. Wollaston, who has thus furnished the laboratory with one of its most useful implements.

The principal materials of this book have been drawn from the notes that I have employed in my different courses of lectures, and these are partly original, and partly compiled from various sources; although therefore I have in most intances scrupulously referred to the authorities quoted, it is possible that this may have been sometimes omitted, and for such omissions, I now beg to



Scoles sculp.

Plantation.

apologize. The systematic and elementary works that I have chiefly relied on for assistance, are the *Systems* of Dr. T. Thomson, and of the late Dr. John Murray; the *Traite de Chimie* of M. Thenard; and the *Elements* of Sir Humphry Davy, and of Dr. William Henry. The *Chemical Dictionary* of Messrs. Aikin, I have also often consulted with advantage, especially in relation to the Chemistry of the Arts. Dr. Ure's *Dictionary of Chemistry* did not fall into my hands till this work was nearly ready for publication, or I should have availed myself of the valuable information in which it abounds, both original and compiled.

I think it also right to add, that much of this work has been written in the Laboratory, where the results of experiments have been immediately transferred to its pages; and where I have uniformly received the assistance of Mr. M. Faraday, whose accuracy and skill as an operator have proved of essential service in all my proceedings.

The following description of the ground plan (Plate I.) will serve to explain its general arrangement.

A is a part appropriated to an audience. B is the body of the Laboratory.

a The entrance.

b An open chimney for the reception of moveable furnaces.

c A wind furnace. (Plate III., *Fig.* 2.)

d A reverberatory and assay furnace.

e A stove with a sunk flue, for warming the Laboratory.

f A table.

g A sand furnace. (Plate III., *Fig.* 1.)

This has lately been transferred to the place of the centre table *p*, and communicates by a descending flue with the same chimney.

h A sink with a plentiful supply of water.

i A table with cupboards below it.

k A furnace for the production of gas from coal, *&c.*

l A cast-iron steam boiler for the abundant supply of hot water, and of steam when required.

m A recess lighted from above, containing a bellows-blowpipe, and communicating with three flues *n n n*, for the reception of the chimneys of portable furnaces. The gas purifiers also stand in this recess.

o A forge furnace placed in a similar recess, with flues for occasional purposes.

p p p Tables with drawers.

q A gasometer from which tubes issue for the supply of the Laboratory, and of the lecture room, with coal gas.

r A small store-room and cellar for fuel, *&c.*

s s Recesses for apparatus.

t Doorway leading to an apartment for apparatus, *&c.*

Plate III. contains a representation of the most useful furnaces of the Laboratory.

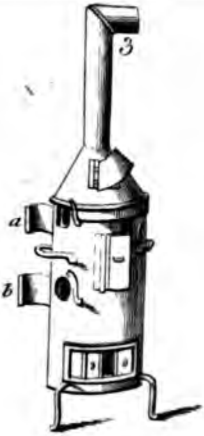
Fig. 1. A sand furnace; *a* the larger bath; *b* the smaller one, which may occasionally be removed for the purpose of employing the fire-place for crucibles, or of inserting the boiler of a still.

Fig. 2. Section of the wind-furnace; *c* Plate I. *a* is a flue communicating with the exterior of the building, for the admission of cold air to the fire-place; *b* the ash-hole; *c c* two grates, the upper of which may be removed when a deep fire-place is wanted; *d* an aperture which may be closed by a moveable fire-brick; *e* the chimney; *f* a register.

Fig. 3. Knight's portable furnace, made of wrought iron, and lined with fire-brick. It is convenient for a variety of operations, conducted upon a small scale; *a* is a door for the passage of the neck of a retort when distillation is performing in the open fire, as seen in the wood-cut at page 120; *b* is an aperture to which there is a corresponding one on the opposite side for the admission of a tube to pass through the furnace, as shown at page 81.

Fig. 4. A portable assay-furnace; *a* is the muffle represented in Fig. 5.

Fig. 6, 7, and 8, are evaporating basins; 9, a Platinum crucible and cover; 10, 11, Hessian crucibles; 12, 13, 14, 15, the principal varieties of tongs useful in the Laboratory.



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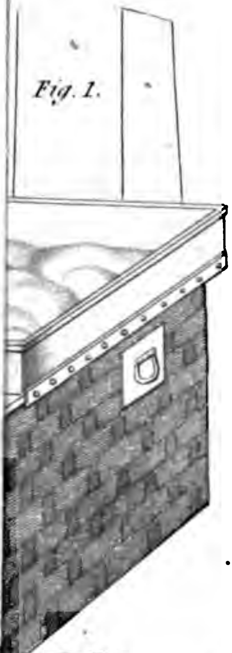
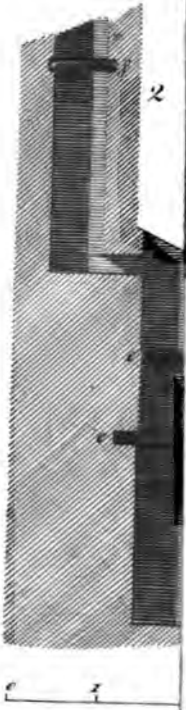


Fig. 1.



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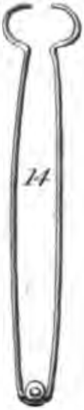

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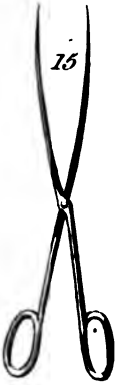

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Scoles, sculp.

A

MANUAL OF CHEMISTRY.

CHAPTER I.

OF THE POWERS AND PROPERTIES OF MATTER, AND OF THE GENERAL LAWS OF CHEMICAL CHANGES.

Object of Chemistry.

1. IT *is the object of Chemistry to investigate* all changes in the constitution of matter, whether effected by heat, mixture or other means. Its general range, therefore, is so extensive, and the individual cases requiring explanation, so numerous, that *Arrangement* is of the first consequence to its successful study; and, in the present state of our knowledge, it will be found most convenient to begin with the discussions relating to the general powers or properties of matter, and afterwards to proceed to the examination of individual substances, and to the phænomena which they offer when presented to each other under circumstances favourable to the exertion of their mutual chemical agencies.

2. The powers and properties of matter, connected with chemical changes, may be considered under the heads of

1. Homogeneous Attraction.
2. Heterogeneous Attraction, or Affinity.
3. Heat.
4. Electricity.

SECTION I. *Homogeneous Attraction.*

Attraction at sensible distances.

3. ATTRACTION may be regarded as acting at sensible and at insensible distances. In the former case it is called *gravitation*. It is the power by which substances are propelled towards the earth; it exists in all known forms of matter; and it acts directly as the mass, and inversely as the square of the distance: Restrained by *inertia*, it preserves the planetary bodies in their orbits, presides over their movements, and tends to confer upon the system of the universe that consummate harmony which the genius of Newton has unveiled.

Attraction at insensible distances.

4. Attraction is also exerted at insensible distances, and among the minutest atoms of matter. It thus preserves the form, and modifies the texture, of solids, gives a spherical figure to fluids, causes the ad-

hesion of surfaces, and influences the mechanical characters of bodies; and, when it operates upon *dissimilar* particles, it produces their union, giving rise to new and infinitely-varied productions.

5. The results of attraction, as relating to the texture and forms of matter, are influenced by the circumstances under which it has taken place. Sometimes the particles are, as it were, indiscriminately collected; at others, they are beautifully arranged, giving rise to regular and determinate figures: In this case, bodies of the same composition almost invariably affect the same form; hence we are often enabled to infer the composition of a substance from accurate inspection of its external or mechanical characters.

6. The regular polyhedral solids thus resulting from the influence of attraction upon certain kinds of matter, are usually called *crystals;* and the bodies are said to be susceptible of *crystallization.*

Conditions for crystallization.

7. To enable the particles of bodies to assume that regular form which chrystals exhibit, it is obvious that they must have freedom of motion; and accordingly, the first step towards obtaining a body in its crystalline form, is to confer upon it either the liquid or aëriform state. The former is usually effected by solution in water; the latter by exposure to heat.

8. When common salt is dissolved in water, its particles may be regarded as disposed at regular distances throughout the fluid; and if the quantity of water be considerable, the particles will be too far asunder to exert reciprocal attraction; in other words, they will be more powerfully attracted by the water than by each other. If we now slowly get rid of a portion of the water by evaporation, the saline particles will gradually approach each other, and they will aggregate according to certain laws producing a regular solid of a cubic form.

The figure influenced by rapidity of evaporation.

9. The regularity of this figure will be influenced by the rapidity of the evaporation; if the process be slowly conducted, the particles unite with great regularity; if hurried, the crystals are irregular and confused. In common cases, the evaporation may be continued till a pellicle forms upon the surface of the solution, which indicates that the attraction of the saline particles for each other, is becoming superior to their attraction for the water. The formation, therefore, of a superficial pellicle is the common criterion of the fitness of a solution for crystallization; but where the object is to obtain very regular and very large crystals, the evaporation must be much slower, and carried to much less extent; even spontaneous evaporation, or that which takes place at common temperatures, must be resorted to.

Time for stopping artificial evaporation.

Crystals formed by fusion.

10. There are certain bodies which may be dissolved or liquefied by heat, and during slow cooling, may be made to crystallize. This is the case with many of the metals, and with sulphur. Some other substances, when heated, readily assume the state of vapour, and, during condensation, present regular crystalline forms; such as iodine, benzoic acid, camphor, &c.: and in this way crystals of snow are produced by the cooling of aqueous vapour.

Crystallization of substances whose composition is feeble.

11. Some substances are so easily decomposed by heat, and at the same time retain water with such avidity, that it is impossible to crystallize them by any of the above processes; in these cases crystallization may sometimes be effected by placing the solution under the exhausted receiver of an air-pump, over a surface of sulphuric acid, which by ab-

sorbing the vapour as it rises, causes rapid evaporation without increase of temperature.

water of crystallization.

12. The hardness, brilliancy, and transparency of crystals, often depend upon their containing water, which sometimes exists in them in large quantities. Thus, sulphate of soda, in the state of crystals, contains more than half its weight. Sulphate of lime, in its crystallized form, contains about 20 per cent, of water, which it loses at a red heat, and the crystals crumble down into the white powder called Plaster of Paris. This is termed *water of crystallization*. Some salts part with it by simple exposure to a dry air, when they are said to *effloresce*; but there are other salts which *deliquesce*, or attract water from the atmosphere. Those crystals which effloresce by exposure to air, may often be conveniently preserved, by slightly oiling their surfaces. The best method is, to soak the crystals in oil for a few hours, and then to wipe them, and put them up in bottles.

Efflorescence and deliquescence.

13. Some salts, in consequence probably of their strong attraction for the water that retains them in solution, cannot be brought to crystallize in the ordinary way. In such cases, crystallization may sometimes be effected by the addition of substances having a strong affinity for water, by which its attraction for the dissolved matters is weakened: thus alcohol, added to certain aqueous saline solutions, produces a separation of crystals, but they are generally small and indistinct.

14. *When two salts of different solubilities* are present in the same solution, they often may be separated by crystallization, that which is least soluble constituting the earlier crop of crystals.

Crystallization promote by a nucleus.

15. Crystallization is accelerated, by introducing into the solution a nucleus, or solid body, upon which the process begins; and manufacturers often avail themselves of this circumstance. Thus we see sugar-candy crystallized upon strings, and verdigris upon sticks. There are cases in which it is particularly advantageous to put a few crystals of the dissolved salt into the solution, which soon cause a crop of fresh crystals; and in some instances, if there be two salts in solution, that will most readily separate, of which the crystals have been introduced.

crystallizatio affected by th admission o air as also b agitation.

16. A strong saline solution, excluded from the air, will frequently crystallize the instant that air is admitted,—a circumstance unsatisfactorily referred to atmospheric pressure. In other cases, agitation produces the same effect. These phænomena seem connected with the doctrine of latent heat, but hitherto they have only been imperfectly investigated: in some cases they have been shown by Dr. Ure to be affected by electrical changes.—*Quarterly Journal*, Vol. x., p. 6.

Light influences crystallization.

17. The presence of light also influences the process of crystallization. Thus we see the crystals collected in camphor bottles in druggists' windows always most copious upon the surface exposed to light; and if we place a solution of nitre in a room which has the light admitted only through a small hole in the window shutter, crystals will form most abundantly upon the side of the basin exposed to the aperture through which the light enters, and often the whole mass of crystals will turn towards it.

Many saline solutions form arborescent crystalline pellicles, when left to spontaneous evaporation, which slowly travel up the sides of the basin, and gradually proceed down upon the outside: this process also always begins on the side nearest the light, and is often confined to it. Acetate of lime exhibits this appearance in a very beautiful manner.—Aikin's *Dict.* Art. Light.

Structure of crystallized bodies.

18. We may now proceed to examine the structure of crystallized bodies, upon which the *Theories of Crystallization* are founded. This inquiry exposes a connecting link between the Chemical and Mechanical properties of bodies.

Assume one form rather than another.

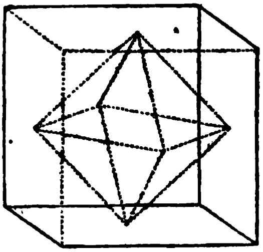
It is commonly observed, that crystallized bodies affect one form in preference to others. The fluor spar of Derbyshire crystallizes in cubes: so does common salt. Nitre assumes the form of a six-sided prism, and sulphate of magnesia that of a four-sided prism. These forms are liable to vary. Fluor spar and salt crystallize sometimes in the form of octoëdra; and there are so many forms of carbonate of lime, that it is difficult to select that which most commonly occurs.

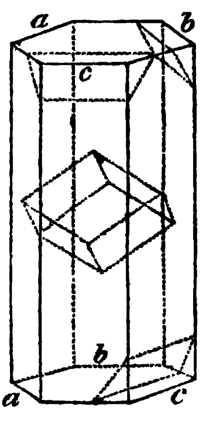
All varieties of crystals of the same substance have similar nuclei.

Romé de Lisle referred these variations of form to certain truncations of an invariable primitive nucleus; and Gahn afterwards observed, that when a piece of calcareous spar was carefully broken, all its particles were of a rhomboidal figure. This induced Bergman to suspect the existence of a primitive nucleus in all crystallized bodies (*Physical and Chemical Essays*, Vol. II. p. 1.) When Haüy entered this field of inquiry, he not only corroborated the opinions of Bergman, and submitted former hypotheses to experimental proof, but traced with much success the laws of crystallization and pointed out the modes of transition from primitive to secondary figures.—*Traitéde Minéralogie*, Paris, 1801.

Gems cannot be split smoothly but in certain directions.

19. Those who are in the habit of cutting and polishing certain gems, have long known that they only afford smooth surfaces when broken in one direction; and that in others the fracture is irregular and uneven. This is the case with crystallized bodies in general. If we attempt to split a cube of fluor spar with the blade of a knife assisted by a hammer we shall find that it will only yield kindly in the direction of the solid angles; and pursuing the divivision in these directions an octoëdron will be the resulting figure as in this diagram.



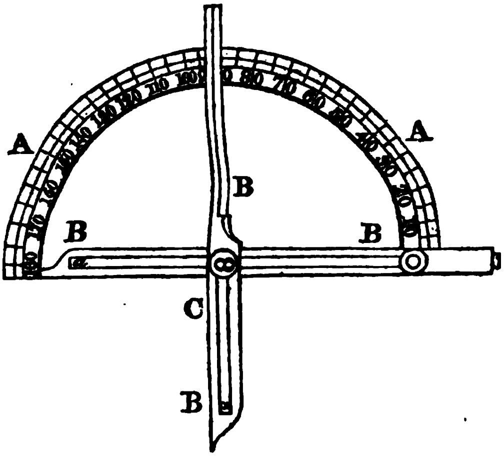


20. In splitting a six-sided crystal of calcareous spar, we find that of the six edges of the superior base, three alternate edges only will yield to the blow: those, for instance, marked *a*, *b*, *c*; and the division will take place in a plane inclined at an angle of 45°. The three intermediate edges resist this division. But in dissecting the inferior base of the crystal, the intermediate edges will alone yield, namely, *a*, *b*, *c*. If we continue this dissection in the same directions, we shall at length obtain the obtuse rhomboid, which is seen in this diagram in its Relative situation to the including prism.

21. We thus then arrive at the *primitive form* of the calcareous spar, and from whatever secondary form it has been obtained, it is always a rhomboid, having obtuse angles of 105° 5′. But an obtuse rhomboid, is also the primitive form of other bodies, as of pearl spar, iron spar, and tourmalin. But here the inclination of the surface points out a difference. Thus the primitive angle of pearl spar is 106° 5′, of iron spar 107°, (Wollaston, *Phil. Trans.* 1812,) and of tourmalin 113° 10′.

Instrument for measuring the angles of crystals.

22. These instances show the necessity of being provided with instruments for measuring the angles of crystals with nice accuracy; they are termed *goniometers*. The simplest of these instruments consists of a protractor or seme-circular scale of degrees, AA, and a small pair of compasses or nippers, B B B B, destined to receive the crystal.



Simplest form of the goniometer.

Description.

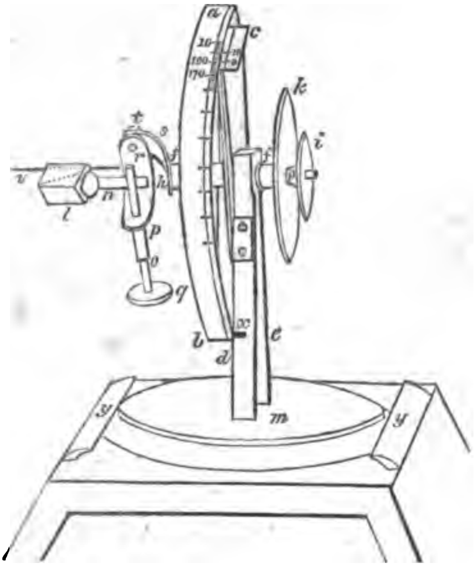
The centre of the pair of compasses is made moveable like those of the common proportional compasses, so as to permit the legs B B, and B C B, to be considerably lengthened or shortened, when the two pieces are applied to each other. The fixed leg B B, is represented as beneath the moveable one B C B, or radius, measuring 90°, and the lower end of the centre pin, which could not be shown in the wood cut, is made to fit the hole or centre in the protractor precisely at the same time that a stud or projecting piece of brass, being admitted into the long perforation *a* of the leg B B, the piece becomes steadily attached to the protractor or semi-circle, as is seen in the Figure.

Application.

The application of this instrument is obvious. The crystal to be measured is applied between the compasses, which being thus set, are applied to the protractor, and the value of the angle may be read off at the fiducial edge of the leg B C B.

23. The reflective goniometer, invented by Dr. Wollaston (*Phil. Trans.* 1809,) is the most useful of these instruments. It enables us to determine the angles even of minute crystals with great accuracy; a ray of light reflected from the surface of the crystal being employed as radius, instead of the surface itself. Mr. W. Philips has given the following description and practical details for the use of this instru-

ment, in his *Introduction to Mineralogy*, which, with his permission, I here transcribe.



Description.

"*a b* Is the principal circle graduated on one edge to half degrees, and divided for convenience into two parts of 180° each; (it is gragraduated only in part in the above sketch.)

"*c* Is a brass plate, screwed upon, and supported by the pillar *d*, and graduated as a vernier.

"*f f* Is the axle of the circle *a b*, and passes through the upper part of the two pillars *d e*, the other ends of which are inserted into a wooden base *m*.

"*g h* Is an axle, enclosed within *f f*, and turned by means of the smallest circle *i*, which communicates a motion to all the apparatus on the left of *h*, without moving the principal circle *a b*.

"*k* Is a circle, to which is attached the axle of the principal circle. If therefore we would move the latter, it will be done by moving *k*; and as the axle of the principal circle includes that of the apparatus on the left of *h*, we necessarily give a motion to the whole instrument by moving the circle *k*.

"These two movements being understood, let us now suppose that we want to measure a crystal; a rhomboid of carbonate of lime, for instance.

"Let *l* be the rhomboid, attached by means of wax to one end of a plate of brass *n*; the other end of the plate being placed in a slit in the upper part of the circular brass stem *o*, which passes through the tube *p*, to which it is so adjusted as to allow of being moved either up or down, or circularly, by means of the circle *q*.

"The tube *p* is fixed to the curved brass plate *r*, which is attached, but so as to allow of motion, to another curved plate *s*, by means of a pin *t*, the other end of the latter plate being connected with the concealed axle *g h*, to which a motion is given by turning the little circle *i*.

"By means of the pin *t* and the tube *p*, therefore, we have two motions, in addition to the two before described as belonging to the axles of the instrument. The inner axle, however, may be said to be the centre of all the motions. It will therefore be of advantage that the rhomboid of carbonate of lime should be placed as nearly *on a line with that axle* as possible: this will be sufficiently adjusted by means of the stem *o*, which admits of being raised or depressed at pleasure.

"The use of this instrument depends on the reflecting power of the polish on the natural planes, or fractured surfaces of minerals: and that this is in some cases very powerful, any one may convince himself Application. by looking upon a very brilliant plane, held beneath the eye, with its edge nearly touching the lower lid, and not far distant from a window; he will then observe the reflection of the bars very distinctly.

"Let us then suppose the goniometer, as above represented, to be distant from a window from eight to twenty feet.

"Let then *v* be a *black line* (the use of this is essential) drawn on the wainscot between the window and the floor, and *perfectly parallel* with the horizontal bars of the window.

"If, then, the eye be placed almost close to the rhomboid *l*, a reflection of one of the bars will be seen on one of its planes.

"Let us suppose the reflection to be in the direction of the lower dotted line on the plane; and it will be clear that it cannot be parallel with the bar of the window, not being even with the black line *v*. It must therefore be adjusted. This may perhaps be done by slightly drawing to the left the circle *q*, which communicates motion by means of the pin *t*; or perhaps it may be done by giving a circular motion to the stem *o*. By one of these two motions, or by both, it may certainly be effected.

"If, however, the reflection appears to be like the upper dotted line, that is, parallel with the black line *v*, we must first convince ourselves that it is so, simply by depressing the crystal a little by means of moving the little circle *i*, so as to bring the reflection *upon the black line*.

"This being adjusted, which must be done precisely, we then turn the crystal, by turning the little circle *i*, until the reflection of the *same bar* be seen on the next plane, perfectly *on a line with and upon the black line v*.

"However, in adjusting the second, we may disturb the first reflection. By perseverance it will be found that both can be adjusted by means of one or other of the movements by the stem *o*, or the pin *t*, or by the help of both, and a short experience will do away the chief difficulties.

"Both reflections being precise, we are now, by means of the circle *k*, to turn the principal circle until it is arrested by the stop *x* on the pillar *d*; it will then be found that one hundred and eighty on the principal circle, coincides with *o* on the vernier.

"In doing this, however, we may slightly disarrange the reflections on the plane of the crystal, which may be re-adjusted simply by moving the little circle *i*, which will not disturb the principal circle *a*, *b*:

we must be certain, however, *that one hundred and eighty on it forms a line with* o *on the vernier, at the same time that the reflection of the bar is seen along the black line.*

"One movement more, and the measurement will have been made. Turn the circle *k*, keeping the eye almost close to the rhomboid, until the reflection of the *same bar* is seen on the adjoining plane *precisely upon the black line v*, and the operation is completed.

"It must then be observed what proportion of the principle circle has been moved. Suppose that 105 on it, be now on a line with *o* on the vernier;—it is the value of the angle. But suppose it to be a little more than 105 and less than 105½: it must then be observed *which line of the vernier touches, or forms but one line with*, another line on the principal circle: suppose it to be 5 on the vernier, the angle is then 105° 5′, which is the true value of the obtuse angle of a rhomboid of carbonate of lime.

"I have been the more particular in the above description from being aware that the use of this elegant instrument is commonly considered to be extremely difficult, and that it is by some supposed, that, in taking an angle, it is essential to keep the head in one position, which will clearly appear not to be requisite. We may, on the contrary perform any part of the operation, and after the lapse of hours complete it.

Further remarks upon its accurate use.

"It may not be amiss to subjoin a few hints connected with its accurate use. In the first place, it should be observed, that when the circle is arrested by the stop *x*, 180° on it is precisely on a line with *o* on the vernier: this must be exact.

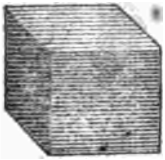
"Some difficulty will at first be found in attaching the fragment of the crystal to the wax (which must be warmed,) nearly in the required position. In doing this, it will be found of some advantage to hold the mineral in such a direction, that the edge between the two planes to be measured, shall be in a horizontal position, and, as nearly as possible, parallel with the bar of the window. It will be best to begin with some substance which is brilliant not more than one-third of an inch in diameter, and of which the angles are known. Fragments of transparent calcareous spar, or sulphate of barytes, are well adapted.

"The perfect steadiness of the instrument is essential. A small, square, and very solid table, standing firmly, will be useful: but this may not be high enough to raise the instrument to the eye of the observer without supporting the goniometer, which must be so fixed as not to shift its place while moving the circles, or by a casual touch. Supposing the table to be of the ordinary height, some support for the goniometer a foot above it, will be requisite to elevate it to the eye of an observer while sitting. This support should be made in the form of a pyramid, with a perfectly flat base, and a truncated summit, on which the goniometer may stand, or rather may be fixed, by sliding its wooden base *m* along it; so that, in two opposite places, it shall be confined by two pieces of wood *y y*, hollowed for the purpose of receiving it. This pyramid will afford an opening in the upper part for the goniometer when out of use, while the lower may be conveniently cupied by a drawer."

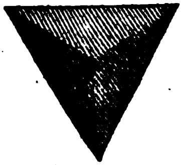
24. In following the method above described, (20) Haüy obtained six *primitive* forms.

Haüy's primitive forms.

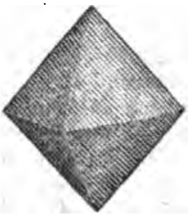
i. The cube, parallelopipedon, *&c.*



ii. The tetraëdron.

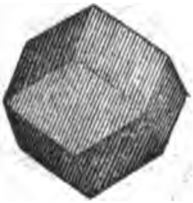


iii. The octoëdron.

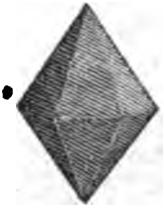


iv. The hexangular prism.

v. The rhombic dodecaëdron.



vi. The dodecaëdron with isoceles triangular faces.

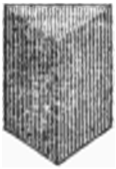


Integral elements.

25. These primitive forms, by further mechanical analysis may be reduced to three *integral elements*.

i. The parallelopiped, or simplest solid, having six surfaces, parallel two and two. (24. i.)

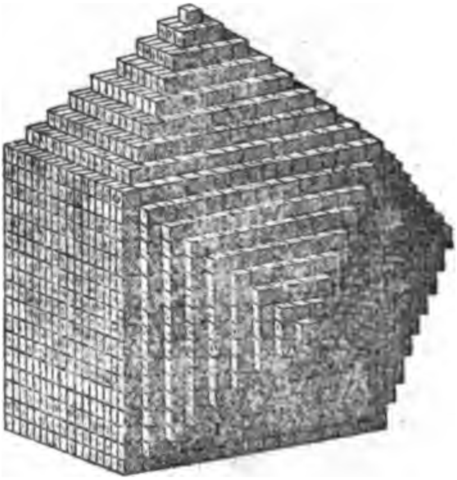
ii. The triangular, or simplest prism, bounded by five surfaces.

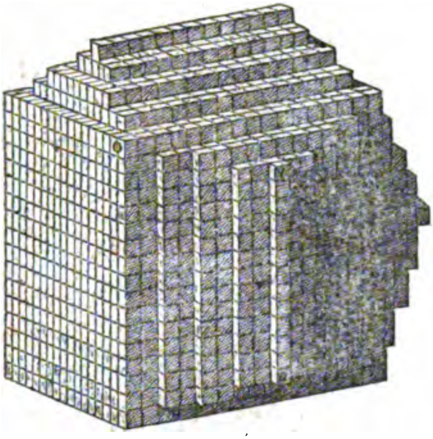


iii. The tetraëdron, or simplest pyramid, bounded by four surfaces. (24. ii.)

Theory of secondary forms.

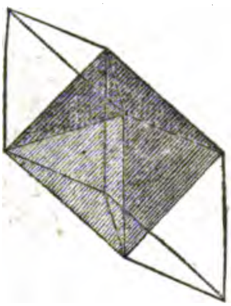
26. The *secondary* forms are supposed to arise from decrements of particles taking place on different edges and angles of the primitive forms. Thus a cube, having a series of decreasing layers of cubic particles upon each of its six faces, will become a dodecaëdron, if the decrement be upon the edges; but an octoëdron, if upon the angles; and by irregular, intermediate, and mixed decrements, an infinite variety of secondary forms would ensue, as the annexed figures show.





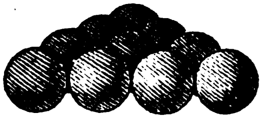
Objections to Haüy's theory.

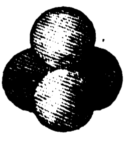
27. But in crystallography we meet with appearances which Haüy's theory but imperfectly explains. A slice of fluor spar, for instance, obtained by making two successive and parallel sections, may be divided into acute rhomboids; but these are not the primitive form of the spar, because by the removal of a tetraëdron from each extremity of the rhomboid an octoëdron is obtained. Thus, as the whole mass of fluor may be divided into tetraëdra and octoëdra, it becomes a question which of these forms is to be called primitive, especially as neither of them can fill space without leaving vacuities, nor can they produce any arrangement sufficiently stable to form the basis of a permanent crystal.

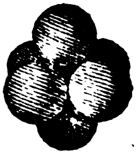


Wollaston's theory.

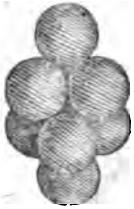
28. To obviate this incongruity, Dr. Wollaston (*Phil. Trans.* 1813,) has very ingeniously proposed to consider the primitive particles as spheres, which, by mutual attraction, have assumed that arrangement which brings them as near as possible to each other. When a number of similar balls are pressed together in the same plane, they form equilateral triangles with each other; and if balls so placed were cemented together and afterwards broken asunder, the straight lines in which they would be disposed to separate, would form angles of 60° with each other. A single ball, placed any where on this stratum, would touch three of the lower balls, and the planes touching their surfaces would then include a regular tetraëdron. A square of four balls, with a single ball resting upon the centre of each surface, would form an octoëdron; and upon applying two other balls at opposite sides of







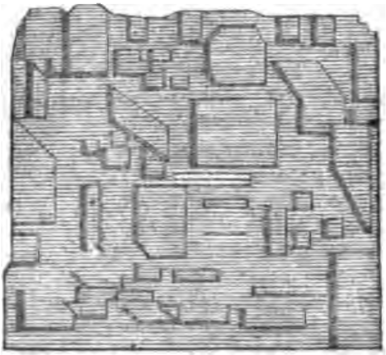
this octoëdron, the group will represent the acute rhomboid. Thus the difficulty of the primitive form of fluor, above alluded to, is done away, by assuming a sphere as the ultimate molecula. By oblate and oblong spheroids other forms may be obtained.

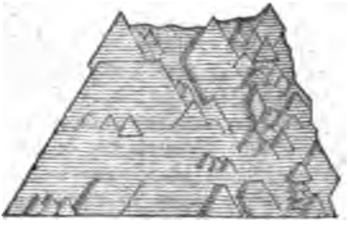


A sphere the ultimate molecule.

Confirmation of Wollaston's theory.

29. The subject of crystallization has more lately engaged the attention of Mr. J. F. Daniel (*Quarterly Journal of Science and the Arts*, Vol. i.) and his researches have produced some singular confirmations of Dr. Wollaston's hypothesis. If an amorphous piece of alum be immersed in water and left quietly to dissolve, at the end of about three weeks we shall observe that it has been unequally acted upon by the fluid: the mass will present the forms of octoëdra, and sections of octoëdra, as it were carved or stamped upon its surface, as seen in these figures:





This appearance is produced when the attraction of the water for the solid is nearly counter-balanced by its mechanical texture. The crystals formed by this species of dissection are highly curious, from their modifications and relative positions, as the same group presents the primitive form as well as its truncations and decrements. Other salts yield other figures, and by more complicated chemical action, as of acids upon carbonate of lime, the metals, *&c.*, analogous results are obtained. Here then, instead of dividing a crystal by mechanical force its structure is gradually developed by the process of solution. In these cases two circumstances are particularly remarkable : the crystals are different ; and their forms vary with the different faces of the original mass. In one direction we observe octoëdra and sections of octoëdra ; in another, parallelograms of every dimension, modified with certain determinate intersections.

If, in neither of these positions, we turn the mass upon its axis, the same figures will be perceived at every quadrant of a circle ; and, if we suppose the planes continued, they will mutually intersect each other, and various geometrical solids will be constructed. In this way, alum alone furnishes octoëdrons, tetraëdrons, cubes, four and eight-sided prisms either with plain or pyramidal terminations, and rhombic parallelopipedons. It is evident, then that no theory of crystallization can be admitted, which is not founded upon such a disposition of constituent particles, as may furnish all these modifications, by mere abstraction of certain individuals from the congeries, without altering the original relative position of those which remain ; and these conditions may *be fulfilled by such an arrangement of spherical particles*, as would arise *from the combination of an indefinite number of* balls endued with mutual attraction and no other geometrical solid is adequate to the purpose ; and where bodies afford crystals differing from the octoëdral series, an analogous explanation is furnished, by supposing their constituent particles to consist of oblate spheroids, whose axes bear different proportions to each other in different substances. Hence we may also conclude, that the internal structure of all crystals of the same body is alike, however the external shapes differ. In corroboration of the above hypothesis, we may remark, that the hexaëdron is, of all geometrical figures, that which includes the greatest capacity under the least surface. If, therefore, the ultimate particles of crystalline bodies be spheres or spheroids, the greatest possible number in the least space will be included in this form. It is probable that the exterior shape of every crystal is determined by the nucleus first formed by a certain definite number of particles, which, by the power of mutual attraction, overcome the resistance of the medium in which they were suspended or from which they were separated. This number may vary with the solvent, or other contingent circumstances. Four spherical particles, thus united, would balance each other in a tetraëdral group, six in an octoëdral group, and each would present particular points of attraction to which all subsequent deposits would be directed. Now, let us imagine two nuclei formed in the same solution, whose axes run in contrary directions ; their increase will consequently be in contrary directions, and each will attract a particular system of particles from the surrounding medium. If these two systems should cross each other in their course, a greater number will be brought within the sphere of mutual re-action at the point of junction, and they ought to arrange themselves in the least possible compass. The facts here answer to the theory. If we select any crystals, having others crossing them nearly at right angles, and separate them, the points of junction invariably present an hexaëdral arrangement.

Several conditions for a theory.

Internal structure of all crystals of the same body uniform.

Probability that the exterior shape varies with and depends upon the number of particles united in the nucleus.

Their number may vary with the solvents, &c.

The plane of intersection between two crystals a hexagon.

Connexion of crystallization with chemistry.

30. In connexion with chemistry, the theory of crystallization opens a new avenue to the science, and frequently enables us to ascertain directly, that which, independent of such aids, could only be arrived at by an indirect and circuitous route. We frequently read the chemical nature of substances in their mechanical forms. To the mineralogist, an intimate acquaintance with the crystalline forms and modifications of natural bodies is essentially requisite. Indeed, the theory of crystallization may be considered as one of the great suports of that useful branch of natural history, and it is to the indefatigable exertions of Haüy that much of its present perfection is to be referred. In the arts, the process of crystallization is turned to very valuable account, in the separation and purification of a variety of substances.

SECTION II. *Heterogeneous Attraction, or Affinity.*

Chemical attraction or affinity.

31. We have hitherto considered Attraction as disposing the particles of bodies to adhere so as to form masses or aggregates; and, in many instances, to arrange themselves according to peculiar laws, and to assume regular geometrical figures. We are now to regard this power as operating upon dissimilar particles; as presiding over the composition of bodies; and as producing their chemical varieties. This is CHEMICAL ATTRACTION, OR AFFINITY.

Result of this attraction.

32. If, into a glass vessel, exhausted of air, be introduced some sulphur, and copper filings, and heat applied so as to melt the former, it will presently combine with the latter. We observe, as the results of this attraction between the sulphur and copper, 1. That the substance produced has not the intermediate properties of its elements, but that it presents new characters. 2. That much heat and light are evolved during the mutual action. 3. That sulphur and copper will unite in certain proportions only.

Solid products

Gaseous

Liquid.

33. In liquids and gases, similar changes of properties may be exhibited, and, in many cases, a change of form or state results. Thus the combination of aëriform bodies produces a solid, as when muriatic and ammoniacal gases produce the salt called muriate of ammonia. The combustion of gunpowder offers a familiar instance of the conversion of solid into aëriform matter. Gases form a liquid, as when olefiant gas is mixed with chlorine. Solids also produce liquids, as is shown by triturating crystals of Glauber's salt with nitrate of ammonia: and in the action of concentrated solutions of muriate of lime and carbonate of potassa, liquids form a solid. Liquids produce gases, as when one part of nitric acid is mixed with two of alcohol an effervescence ensues, and aeriform matter is copiously evolved.

The compound may have some properties similar to its constituents.

34. In some cases of combination, the resulting compound differs but little from its component parts, and their leading characters are still obvious in it. This is especially remarked in solutions of different substances in water and other fluids. Salt and sugar dissolved in water, retain their saline and sweet tastes, the only physical quality that is changed being that of cohesion.

Distinct properties.

35. In other cases, the properties of the compound differ essential-

ly from those of its component parts, and a series of new bodies, possessed of distinct and peculiar characters, are produced. Thus, when two volumes of nitric oxide gas are mixed with one of oxygen, an orange-coloured gas results, very sour, and soluble in water; whereas, the gases before mixture were colourless, tasteless, and insoluble in water.

Such operations are not confined to art: Nature presents them on an extended scale; and, in connexion with the functions of life, renders them subservient to the most exalted purposes.

36. The new chemical powers, that bodies thus acquire in consequence of combination, are often extremely remarkable, and can only be learned by *experiment.* It frequently happens that inert bodies produce inert compounds, and that active substances remain active when combined; but the reverse often occurs: thus oxygen, sulphur, and water, in themselves tasteless and comparatively inert, produce sulphuric acid when chemically combined; and potassa, which is a powerful caustic, when combined with sulphuric acid, forms a *salt* possessed of little activity.

Other changes produced by chemical action.

37. The colours, the specific gravity, and the temperature of bodies are also commonly altered by chemical action. Thus the *blue* infusion obtained by macerating violets in warm water is rendered *red* by acids, *green* by alcalis, and its *colour is wholly destroyed* by chlorine. When equal parts of sulphuric acid and water are mixed, the resulting liquid has a specific gravity much above the mean; the temperature is also much increased; and ignition frequently attends chemical action. (32.)

Chemical action takes place between elementary matter is therefore opposed to simple cohesion.

Attraction of aggregation acts in opposition.

38. As chemical action takes place among the ultimate or constituent elements of bodies, it must obviously be opposed by the cohesion of their particles, and chemical attraction is often prevented by mechanical aggregation. A piece of the metal antimony, put into the gas called chlorine, is only slowly and superficially acted upon; but if the mechanical aggregation be previously diminished, by reducing the metal to powder, it in that state rapidly unites with the gas, and burns the instant that it is introduced.

Caloric promotes Chem. action.

39. Heat increases the chemical energies of bodies. Its effects are sometimes only referable to the diminution of adhesion by expansion or liquefaction; but in other cases they are peculiar and complicated and probably concerned in modifying the electrical energies of the acting substances.

Simple or elective attraction.

40. Different bodies are possessed of different attractive powers, and if several be brought together, those which have the strongest mutual affinities enter first into union. Thus, if nitric acid be poured upon a mixture of lime and magnesia, it dissolves the former in preference to the latter earth. The knowledge, of this fact, enables us to separate bodies when united, or to perform the process of *decomposition.* Thus if we add an aqueous solution of lime to a solution of magnesia in nitric acid, the latter earth is thrown down or precipitated, and the lime occupies its place in the acid.

41. Upon this principle tables of attraction have been constructed, the substance whose affinities are to be represented being placed at the head of a column, and the bodies with which it combines beneath it, in the order of their respective attractions (see *History of Chemistry*, p. 78.;) thus the affinity of sulphuric acid for several bases would be shewn as follows:

SULPHURIC ACID

Baryta.
Strontia.
Potassa.
Soda.
Lime.
Magnesia.
Ammonia.

From this table it would appear that baryta separates sulphuric acid from its compounds with all the inferior substances, and that ammonia is separated by all that are above it; there are, however, many circumstances which interfere with the usefulness and accuracy of such tables, and in some cases there are anomalies in the mutual agencies of bodies which wholly subvert the usual order of arrangement. One of these has been pointed out by Mr. R. Phillips,—(*Journal of Science and the Arts*, Vol. i., p. 80.) He found that on boiling carbonate of baryta in a solution of sulphate of potassa, sulphate of baryta and carbonate of potassa were formed; and he also found that, on reversing the experiment, by boiling sulphate of baryta in solution of carbonate of potassa carbonate of baryta and sulphate of potassa were produced.

42. Decomposition is effected under a variety of circumstances, and by many methods; but it is commonly described by chemists as SIMPLE and COMPLEX, or SINGLE and DOUBLE.

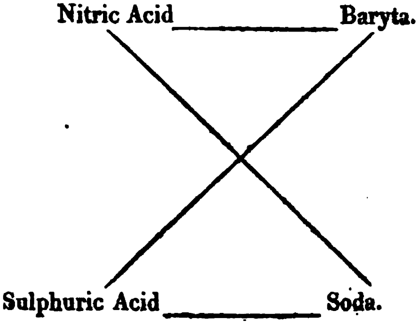
Single decomposition.

43. In cases of simple attraction or affinity, one body separates another from its combination with a third. Thus, when potassa is added to a solution of sulphate of zinc (composed of sulphuric acid and oxide of zinc,) the oxide of zinc is separated, and sulphate of potassa is produced.

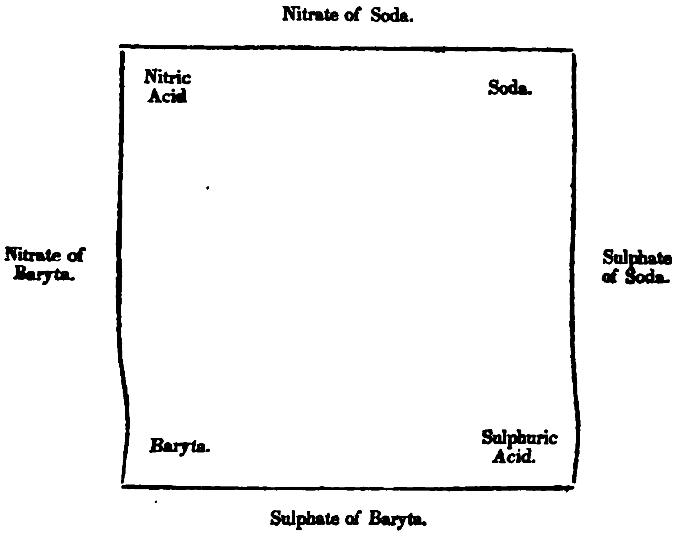
Double decomposition.

44. In cases of double decomposition, two new compounds are produced; as when a solution of nitrate of baryta, is mixed with a solution of sulphate of soda, the results are a precipitate of sulphate of baryta, and a solution of nitrate of soda.

45. These cases of double decomposition are sometimes conveniently illustrated by diagrams, which may either be constructed so as merely to show the result of the change, or where required they may also exhibit the composition of the acting bodies. In the case just alluded to, the substances before mixture are shown by parallel lines, and after mixture by diagonal lines.



Or a more complete view of the change is given in the following diagram, where the bodies before mixture are placed upon the outside of the perpendicular lines; their component parts are shown within them; and the new results on the outside of the horizontal lines.



Chemical affinity governed by definite laws.

46. It is obvious, from the uniform results of chemical action that, affinity must be governed by certain definite laws, by which its results are determined, and upon which its uniformity depends. Attention was first called to this subject by Mr. Higgins in 1789,—(*Comparative View of the Phlogistic and Antiphlogistic Theories.*) He conceived that chemical attraction only prevailed between the ultimate particles of simple elementary matter, and between compound atoms; and, in applying this idea to chemical theory, he expressed by numbers the relative forces of attraction subsisting between the different kinds of ultimate particles and atoms of matter.

Higgins' idea.

Made a system or theory by Dalton.

These views were subsequently extended and improved by Mr. Dalton, and have since engaged the attention of some of the most eminent chemical philosophers; among whom we may enumerate Gay-Lussac and Berzelius, Davy, Wollaston, and Thomson.

46. The *atomic doctrine* or *theory of definite proportionals*, has been much blended with hypothetical views; but it will be most satisfactorily and usefully considered as an independent collection of facts.*

Definite Proportion.

When bodies unite so as to form one compound only, that compound always contains the same relative proportions of its components; and where two bodies unite in more than one proportion, the second, third, *&c.*, proportions are multiples or divisors of the first. This law is well exhibited in the combinations of gaseous bodies. These are seen to unite in simple ratios of volume. Water is composed of hydrogen and oxygen, and 1 part by weight of the former gas, unites to 8 of the latter. The specific gravity of hydrogen compared with that of oxygen, is as 1 to 15; it is obvious, therefore, that one volume of hydrogen unites to half a volume of oxygen, and that the composition of water will be represented by weight and volume thus:

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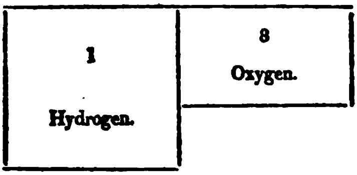
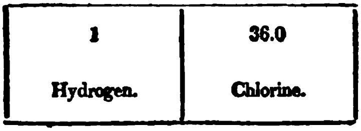
* See note at the end of the volume.



Muriatic acid gas consists of 1 part by weight of hydrogen and 36.0 by weight of chlorine. The relative specific gravities of these gases are as 1 to 36.0. It is obvious, therefore, that they combine in equal volumes, and that muriatic acid gas may be thus represented:



Carbonic acid unites to potassa in two proportions, and forms two definite compounds. In the one, 70 parts of potasso are combined with 30 of carbonic acid; in the other, 70 of potasso are united to 60 of carbonic acid.

Lead combines with oxygen in three proportions; the first compound consists of 100 lead + 8 oxygen; the second, of 100 + 12; the third, of 100 + 16.

Saturation.

47. All cases of chemical combination, in which the qualities of the component parts are no longer to be detected in the compound, or in which a neutral body is produced, are obedient to these laws of union: But in some instances bodies may be said to unite in all proportions, as water and alcohol, *&c.* Other bodies combine in all proportions up to a certain point only, and beyond that, combination no longer ensues. Thus water will take up successive portions of common salt, until at length it refuses to take up more, or is *saturated;* and this always occurs when the water has dissolved a definite weight of the salt.

Neutralisation.

48. The term *neutralization* is applied to cases in which bodies mutually disguise each other's properties, as is especially exemplified in the union of acids with alcalis; as of sulphuric acid, for instance, with solution of potassa. The acid reddens violet juice, and is sour. The potassa converts the blue to green, and is acrid. If the acid solution be gradually added to the alcaline, we shall find that, at a certain point, the taste will neither be acid nor acrid, but slightly saline and bitter, nor will there be any effect produced upon the vegetable blue. Thus the acid is neutralized by the alcali, and the compound has been termed a *neutral salt.*

49. When we have ascertained the proportion in which any two or more bodies of one class, *a b c*, neutralize another body *x* of a different class, it will be found that the same relative proportion of *a b c*, *&c.*, will be required to neutralize any other body of the same class as *x*. Thus, since 100 parts of sulphuric acid, and 68 (omitting fractions,) of muriatic acid, neutralize 118 of potassa, and since 100 of sulphuric

neutralize 71 of lime, we may infer that 68 of muriatic acid will also neutralize 71 of lime.

50. If the quantities of two bodies A and B, that are necessary to saturate a given weight of a third body, be represented by q and r, these quantities may be called *equivalents.* Thus in the above example (49,) 100 parts of sulphuric acid and 68 of muriatic acid, are *equivalents* of each other. A column of equivalent numbers, of great use in chemical calculations, will be found in the tables inserted in another part of this work. By adapting a table of this sort to a moveable scale, on the principle of Gunter's sliding rule, Dr. Wollaston has constructed a *logometric scale of chemical equivalents*, which is capable of solving with great facility many problems of chemistry.—*Phil. Trans.* 1814.

Equivalents.

51. By prosecuting chemical analysis, we arrive at a certain number of *principles* or *elements;* that is, of bodies which have not hitherto been decomposed.

The nature of compound bodies is demonstrated by two kinds of proof—*synthesis* and *analysis.* Synthesis consists in effecting the chemical union of two or more bodies, which by analysis are again separated from each other. The term *proximate analysis* has been applied to the separation of two bodies which are themselves compounded; and *ultimate analysis* to the farther separation of these compounds into their components. The composition of blue vitriol is *synthetically* demonstrated by *uniting* sulphuric acid to oxide of copper—*analytically* by *separating* these *proximate* elements from each other. But the sulphuric acid consists of sulphur and oxygen; and oxide of copper consists of copper and oxygen: consequently, we should say that the *ultimate* component parts of blue vitriol are copper, sulphur, and oxygen.

Modes of ascertaining the Composition of bodies.

◆

SECTION III. *Heat.*

52. HEAT may be considered as a power opposed to attraction, for it tends to separate the particles of bodies; and whenever a body is heated, it is also expanded. Expansion is the most obvious and familiar effect of heat; and it takes place, though in different degrees, in all forms of matter. Solids are the least expansible,—liquids expand more readily than solids,—and gasses or aëriform bodies more than liquids.

Caloric in opposition to attraction.

53. When a body has been expanded by heat, it regains its former dimensions, or *contracts*, when cooled to its former temperature.

It expands most bodies.

54. Different bodies expand differently when equally heated. The metals are the most expansible solids; but among them, zinc expands more than iron, and iron more than platinum.

Bodies possess different powers of expansion.

The following table shows the relative expansibility of some of the metals, when their temperature is raised from the freezing to the boiling point of water.

Table of the expansibility of some metals.

Temperature.	Platinum.	Steel.	Iron.
32°	120000	120000	120000
212°	120104	120147	120151

Temperature.	Copper.	Brass.	Tin.
32°	120000	120000	120000
212°	120204	120230	120290

Temperature.	Lead.	Zinc.	
32°	120000	120000	
212°	120345	120360	

55. Liquids differ also in their relative expansibilities: ether is more expansible than spirit of wine, and spirit more than water, and water more than mercury. Those liquids are generally most expansible which boil at the lowest temperature.

The following Table shows the rate of expansion of several liquids:

Table of the expansion of several fluids.

Temp.	Mercury.	Linseed Oil.	Sulphuric Acid.	Nitric Acid.	Water.	Oil of Turpent.	Alchohol.
32°	100000	100000	—	—	—	—	100000
40	100081	—	99752	99514	—	—	100539
50	100183	—	100000	100000	100023	100000	101105
60	100304	—	100279	100486	100091	100460	101688
70	100406	—	100558	100990	100197	100993	102881
80	100508	—	100806	101530	100332	101471	102890
90	100610	—	101054	102088	100694	101931	103517
100	100712	102760	101317	102620	100908	102446	104169
110	100813	—	101540	103196	—	102943	—
120	100915	—	101834	103776	101404	103421	—
130	101017	—	102097	104352	—	103954	—
140	101119	—	102320	105132	—	104573	—
150	101220	—	102614	—	102017	—	—
160	101322	—	102893	—	—	—	—
170	101424	—	103116	—	—	—	—
180	101526	—	103339	—	—	—	—
190	101628	—	103587	—	103617	—	—
200	101730	—	103911	—	—	—	—
212	101835	107250	—	—	104577	—	—

Rate of expansion among pure gases.

56. In all pure gaseous bodies, the rate of expansion for similar increase of temperature is similar: 100 measures of air, when heated from the freezing to the boiling point of water, suffer an increase in bulk =37,5 parts at mean pressure.

The experiments of Gay-Lussac have proved that steam, and all vapours are subject to laws of expansion similar to those of air,—hence the following Table, showing the changes of bulk suffered by 100000 parts of air at all temperatures between 32° and 212°, will apply equally to all gases and vapours, and will often be found useful to the practical chemist.

Temper.	Bulk.	Temper.	Bulk.	Temper.	Bulk.
32°	100000	59°	105616	86°	111232
33	100208	60	105824	87	111440
34	100416	61	106032	88	111648
35	100624	62	106240	89	111856
36	100833	63	106448	90	112064
37	101040	64	106656	91	112272
38	101248	65	106864	92	112480
39	101459	66	107072	93	112688
40	101666	67	107280	94	112896
41	101872	68	107488	95	113104
42	102080	69	107696	96	113312
43	102290	70	107904	97	113520
44	102496	71	108112	98	113728
45	102708	72	108320	99	113936
46	102916	73	108528	100	114144
47	103124	74	108736	110	116224
48	103333	75	108944	120	118304
49	103536	76	109152	130	120384
50	103749	77	109360	140	122464
51	103952	78	109568	150	124544
52	104166	79	109776	160	126624
53	104368	80	109984	170	128704
54	104576	81	110192	180	130784
55	104791	82	110400	190	132864
56	104992	83	110608	200	134944
57	105200	84	110816	210	137024
58	105408	85	111024	212	137440

Table of expansion for all gases and vapours.

57. The expansion of liquids is not equable for equal additions of heat at different temperatures. Thus the addition of 5° of heat to alcohol at 40°, will produce a less relative increase of bulk than the same addition of heat to alcohol of 100°; and in general, the nearer a liquid approaches its boiling point, the greater is it expansibility. Those liquids therefore appear most equably expansible which have the highest boiling points, and hence one of the great advantages of mercury, as will presently be seen, in constructing thermometers.

Fluids with the highest boiling point expand most equably.

58. As heat increases the bulk of all bodies, it is obvious that change of temperature is constantly producing changes in their density or specific gravity, as may be easily demonstrated in fluids where there is freedom of motion among the particles. If I apply heat to the bottom of a vessel of water, the heated part expands and rises, while a cold or denser stratum occupies its place. In air, similar currents are continually produced, and the vibratory motion observed over chimney pots, and slated roofs which have been heated by the sun, depends

Specific gravity altered by a change of temperature.

upon this circumstance: the warm air rises, and its refracting power being less than that of the circumambient colder air, the currents are rendered visible by the distortion of objects viewed through them.

59. The ventilation of rooms and buildings, can only be perfectly effected by suffering the heated and foul air to pass off through apertures in the ceiling, while fresh air, of any desired temperature, is admitted from below. Various contrivances have been resorted to, to prevent the passage of cold air from above downwards through the ventilator, which can only be completely effected by keeping the ventilating tubes at a higher temperature than the surrounding air; heating them, for instance, by steam; passing them through a fire; or placing a lamp beneath them, of sufficient dimensions to cause a strong current upwards: upon the latter principle, the gas chandelier in Covent-garden theatre being placed under a large funnel, which passes through the roof into the outer air, operates as a very powerful ventilator, all its own heat and smoke passing off with a large proportion of the air of the house.—*Quarterly Journal*, v.

Exception to the law of expansion by caloric.

60. There is only one strict exception to the general law of expansion by heat, and contraction by cold; this is in the case of water, which expands considerably when it approaches its freezing point. Water has attained its maximum of density at 40°, and if it be cooled below 40° it expands as the temperature diminishes, as it does when heated above 40°; and the rate of this expansion is equal for any number of degrees above or below this maximum of density, so that the bulk of water at 32° and at 48° will be the same. Accordingly, if two thermometer tubes, one containing spirit of wine, and the other water, be immersed into melting snow, the former will sink till it indicates 32°; but the latter when it has attained 40° begins to expand, and continues so to do till it freezes.

An apparent object in this anomaly.

This anomaly in respect to water is productive of very important consequences, in preserving the depths of rivers and lakes of a temperature congenial to their inhabitants.

Water expands more in freezing than it does when heated from the freezing to the boiling point.

61. There are many liquids which suffer considerable expansion in passing into the solid state. This is the case with the greater number of saline solutions, and remarkably with water; it seems connected with the phænomena of crystallization, and is referable to a new arrangement of particles. That the force with which water expands in the act of freezing, is very considerable, is shown by the rupture of leaden and iron pipes in which it is suffered to freeze. Dr. Thomson has shown that water in freezing suffers a much greater expansion than when heated from the freezing to the boiling point; for the specific gravity of water at 60° being = 1, that of ice at 32° is only 0.92. Of the metals, Reaumur found that cast-iron, bismuth, and antimony, when expanded in becoming solid; the rest contracted.

Principles upon which thermometers are constructed.

62. If we mix equal quantities of the same fluid at different temperatures, the cold portion will expand as much as the hot portion contracts, and the resulting temperature is the mean; so that it appears, that as much heat as is lost by the one portion is gained by the other. Upon this principle, *thermometers* are constructed. A common thermometer consists of a tube terminated at one end by a bulb, and closed at the other. The bulb and part of the tube are filled with a proper liquid, generally mercury, and a scale is applied, graduated into equal parts. Whenever this instrument is applied to bodies of the same temperature, the mercury, being similarly expanded, indicates the same degree of heat.

63. In dividing the scale of a thermometer, the two fixed points usually resorted to are the freezing and boiling of water, which always take place at

the same temperature, when under the same atmospheric pressure. The intermediate part of the scale is divided into any convenient number of degrees; and it is obvious, that all thermometers thus constructed will indicate the same degree of heat when exposed to the same temperature. In the centigrade thermometer, this space is divided into 100°; the freezing of water being marked 0°, the boiling point 100°. In this country we use Fahrenheit's scale, of which the 0° is placed at 32° below the freezing of water, which, therefore, is marked 32°, and the boiling point 212°, the intermediate space being divided into 180°. Another scale is *Reaumur's*; the freezing point is 0°, the boiling point 80°. These are the principal thermometers used in Europe.

64. Each degree of Fahrenheit's scale is equal to $\frac{4}{9}$ of a degree on Reaumur's: if, therefore, the number of degrees on Fahrenheit's scale, above or below the freezing of water, be multiplied by 4, and divided by 9, the quotient will be the corresponding degree of Reaumur.

Rules for comparing the ordinary thermometers.

Fahrenheit. **Reaumur.**

$68^\circ - 32^\circ = 36 \times 4 = 144 \div 9 = 16^\circ$

$212^\circ - 32^\circ = 180 \times 4 = 720 \div 9 = 80^\circ$

To reduce the degrees of Reaumur to those of Fahrenheit, they are to be multiplied by 9, and divided by 4.

Reaumur. **Fahrenheit.**

$16^\circ \times 9 = 144 \div 4 = 36^\circ + 32^\circ = 68$

$80^\circ \times 9 = 720 \div 4 = 180 + 32^\circ = 212$

Every degree of Fahrenheit is equal to $\frac{5}{9}$ of a degree on the centigrade scale; the reduction, therefore, is as follows:

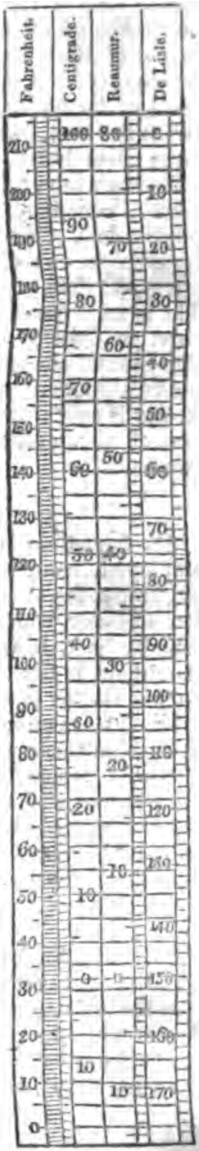
Fahrenheit. **Centigrade.**

$212 - 32 = 180 \times 5 = 900 \div 9 = 100^\circ$

Centigrade. **Fahrenheit.**

$100 \times 9 = 900 \div 5 = 180 + 32 = 212^\circ$

The annexed is a comparative table of the different thermometrical scales, including de Lisle's, in which the graduation commences with the boiling point which is marked 0°, and the freezing 150°.

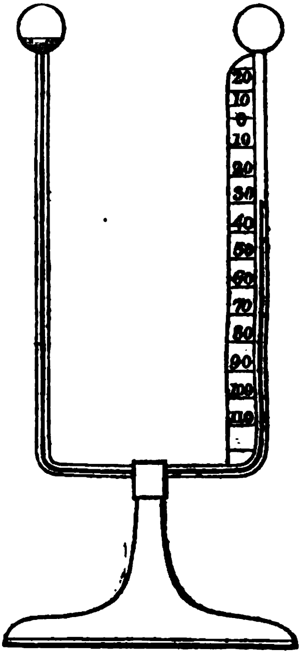


Advantage of spirit of wine.

65. When a thermometer is intended to measure very low temperatures, spirit of wine is employed in its construction, as that fluid has never been frozen, whereas the low temperature at which it boils, renders it unfit for measuring high temperatures. Quicksilver will indicate 500°, but freezes at 40°.

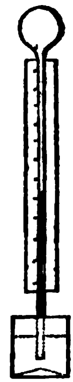
Leslie's differential thermometer of air.

66. Air is sometimes resorted to as indicating very small changes of temperature; and of air thermometers, that described by Professor LESLIE (*Experimental Inquiry into the Nature and Propogation of Heat*, by JOHN LESLIE, London, 1804, p. 9, *&c.*) under the name of the *differential Thermometer*, is the best. It consists of two large glass bulbs containing air, united by a tube twice bent at right angles, containing coloured sulphuric acid. When a hot body approaches one of the bulbs, it drives the fluid towards the other. The great advantage of this instrument in delicate experiments is that general changes of the atmosphere's temperature do not affect it, but it only indicates the *difference* of temperature between the two balls.



Simple air thermometer.

67. Sometimes a simpler form of the air thermometer is employed, consisting merely of a tube with a bulb at one extremity, the other end being open and immersed into coloured water, which by expelling a portion of air from the tube by heat, is made to stand at any convenient height: the liquid in the tube descends and rises on heating and cooling the air in the bulb.



Specific caloric.

68. The relative quantities of heat which different bodies in the same state require to raise them to the same thermometric temperature, is called their *specific* heat, and those bodies which require most heat are said to have the greatest *capacity* for heat. That the quantity of heat in different bodies of the same temperature is different, was first shown by Dr. BLACK, in his lectures at Glasgow in 1762.

Proof of the accuracy of thermometers.

69. It has been stated as a proof of the accuracy of the thermometer, that equal volumes of the same fluid, at different temperatures, give the arithmetical mean, on mixture. Thus, the temperature of a pint of hot and a pint of cold water is, after mixture, as near as possible half-way between the extremes. The cold water being of a temperature of 50°, and the hot of 100°, the mixture raises the thermom-

eter to 75°. But if a pint of quicksilver at 100° be mixed with a pint of water at 50°, the resulting temperature is not 75°, but 70°; so that the quicksilver has lost 30°, whereas the water has only gained 20°. Hence, it appears, that the capacity of mercury for heat is less than that of water; and if the *weight* of the two bodies be compared, which are as 13.3 to 1, their capacities, will be to each other as 19 to 1.

70. In cases where the specific heat of bodies is to be ascertained, it is convenient that water should be the standard of comparison, or $=1$. The following is a general formula for determining the specific heat of bodies, from the temperature resulting from the mixture of two bodies at unequal temperatures, whatever be their respective quantities. Multiply the weight of the water by the difference between its original temperature, and that of the mixture: also, multiply the weight of the other liquid, by the difference between its temperature and that of the mixture: divide the first product by the second, and the quotient will express the specific heat of the other substance, that of water being $=1$. Thus, 20 ounces of water at 105°, mixed with 12 ounces of spermaceti oil at 40°, produce a temperature of 90°. Therefore, multiply 20 by 15 (the difference between 105 and 90) $=300$. And multiply 12 by 50 (the difference between 40 and 90) $=600$. Then $300, \div 600, =\frac{1}{2}$, which is the specific heat of oil; that is, water being $=1$, oil is $=0,5$.

Water the standard for specific heat.

Formula for determining the specific caloric of bodies.

71. *The capacities of bodies for heat have considerable influence upon the rate at which they are heated and cooled. Those bodies* which are most slowly heated and cooled have generally the greatest capacity for heat. Thus, if equal quantities of water and quicksilver be placed at equal distances from the fire, the quicksilver will be more rapidly heated than the water, and the metal will cool most rapidly when carried to a cold place. Upon this principle, Professor Leslie ingeniously determined the specific heat of bodies, observing their relative times of cooling a certain number of degrees, comparatively with water, under similar circumstances.

Leslie's method.

M. M. Petit and Dulong have published some important researches on the subject of specific heat, which render it probable that the atoms of all simple substances have exactly the same capacities for heat.

All atoms seem to have the same capacity for caloric

72. Lavoisier and La Place endeavoured to ascertain the specific heat of bodies by the relative quantities of ice which they were capable of thawing, during cooling: thus, if a pint of water in cooling from 212° to 32° melted a pound of ice, and a pint of oil in passing through the same range of temperature only gave out heat enough to thaw half a pound of ice, it was concluded that the specific heat of water being $=1$, that of the oil was $=0.5$. The instrument which they employed in these researches, and which is fully described in Lavoisier's *Elements of Chemistry*, is not however, susceptible of accuracy, for Mr. Wedgwood has shown that it is scarcely possible to separate the water from the ice.—*Phil. Trans.* Vol. lxxiv.

Lavoisier's method.

73. The capacity of gases and vapours differs with the nature of the gas, and with its density. In gases, dilatation produces cold, and compression excites heat. A thermometer suspended in the receiver of the air-pump sinks during exhaustion, and sudden compression of air produces heat sufficient to inflame tinder. In liquids, too, condensation diminishes capacity for heat; hence the mixture of spirit and water, and of sulphuric acid and water evolves heat. The increased ca-

Dilatation of gases produces cold compression heat.

pacity which air acquires by rarefaction has its influence in modifying natural temperatures. The air, becoming rarer as it ascends, absorbs its own heat and hence becomes cold in proportion as it recedes from the earth's surface: thus moisture, rain, or snow, are thrown down on the mountain-tops.

Conducting power of bodies for caloric.

74. When different bodies are exposed to the same source of heat, they suffer it to pass through them with very different degrees of velocity or they have various *conducting powers* in regard to heat. Among solid bodies, metals are the best conductors; and silver, gold, and copper are better conductors than platinum, iron, and lead. Next to the metals, we may, perhaps, place the diamond, and topaz; then glass; then siliceous and hard stony bodies in general; then soft and porous earthy bodies, and wood; and lastly, down, feathers, wool, and other porous articles of clothing.

Method of determining this power.

75. To compare the relative conducting powers of metals, and some other solids, small cones of the different substances may be used about three inches high, and half an inch in diameter at their bases: these may be tipped at the apex with a small piece of wax, and being placed on a heated metallic plate, will indicate the conducting powers by the relative times required to fuse the wax, which will be directly, as the power of conducting heat.

The difference between the conducting power of the diamond and rock crystal or glass, is shown by applying the tongue to those substances, when the former feels colder than the latter.

From the experiments of Professor Mayer, of Erlangen, (*Annales de Chimie*, tom. xxx.) it would appear that the conducting powers of different woods is in some measure inversely as their specific gravities, as shown by the following table, water being assumed as = 1.

Table of conducting powers.

	Conducting Power.	Specif. Grav.
Water	10	1.000
Ebony Wood	21.7	1.054
Apple tree	27.4	0.639
Ash	30.8	0.631
Beech	32.1	0.692
Hornbeam	32.3	0.690
Plum tree	32.5	0.687
Elm	32.5	0.646
Oak	32.6	0.668
Pear tree	33.2	0.603
Birch	34.1	0.608
Silver fir	37.5	0.495
Alder	38.4	0.484
Scotch fir	38.6	0.408
Norway Spruce	38.9	0.447
Lime	39.0	0.408

Conducting power of clothing substances.

Count Rumford's experiments on the conducting power of several substances used as clothing offer some interesting results, (*Phil. Trans.* 1792.) He found that a thermometer enclosed in a tube and bulb of the same shape, but large enough to allow of an inch vacant space between the two, being previously heated, required 576 seconds to cool 135°. When 16 grains of lint were diffused through the confined air, it took 1032 seconds to undergo the same change of temperature; and 1305 seconds with the same weight of Eider-down. The compression of flocculent substances to a certain extent, renders them still inferior conductors: thus, when the space which in the above experiments contained 16 grains of Eider-down was filled with 32, and then with 64 grains, the times required for the escape of 60 degrees of heat were successively increased from 1305″ to 1472″ and 1615″.

Effect of texture.

On the other hand to show the effect of mere *texture*, similar comparative trials were made of the conducting powers of equal weights of raw silk, of ravelings of white taffeta, and of common sewing silk, of which the first has the finest fibre, the second less fine, and the third from being twisted and harder is much coarser. The difference between these three modifications of the same substance is very striking the raw silk detaining the heat for 1284″, the taffeta ravelings 1169″, and the silk thread only 917″.—AIKIN's *Dict.* ART. CALORIC.

Liquids and gas imperfect conductors.

76. Liquids and gases are very imperfect conductors of heat, and heat is generally distributed through them by a change of specific gravity, as before stated (58. 59.)

If we apply heat to the upper surface of any fluid, it will with great difficulty make its way downwards. Count Rumford considered fluids as non-conductors of heat; but the more accurate researches of Dalton, Hope, Murray, (*System of Chemistry*, Vol. i.,) and Thomson, (*System of Chemistry*, Vol. i.,) have demonstrated that they do conduct, though very imperfectly.

Thus, if we carefully pour hot oil upon water in a tall glass jar with delicate thermometers placed at different distances under the surface, it will be found that those near the heated surface indicate increase of temperature: it might here be said that the heat was conducted by the sides of the jar, and so communicated to the water; to obviate such objection, Mr. Murray made the experiment in a vessel of ice, which being converted into water at 32°, cannot convey any degree of heat above 32° downwards; yet the thermometers were affected, as in the former trial.

Experiments on the conducting power of air are complex and difficult, and the results hitherto obtained are unsatisfactory. They are interfered with by several circumstances hereafter to be noticed, and especially by radiation.

77. The different conducting powers of bodies in respect to heat, are shown in the application of wooden handles to metallic vessels; or a stratum of ivory or wood is interposed between the hot vessel and the metal handle. The transfer of heat is thus prevented. Heat is confined by bad conductors; hence clothing for cold climates consists of woolen materials; hence, too, the walls of furnaces are composed of clay and sand. Confined air is a very bad conductor of heat; hence the advantage of double doors to furnaces, to prevent the escape of heat; and of a double wall, with an interposed stratum of air, to an icehouse, which prevents the influx of heat from without.

Sensations of heat and cold.

78. From the different conducting powers of bodies in respect to heat, arise the sensations of heat and cold experienced upon their application to our organs, though their thermometric temperature is similar. Good conductors occasion, when touched, a greater sensation of heat and cold than bad ones. Metal feels cold because it readily carries off the heat of the body; and we cannot touch a piece of metal immersed in air of a temperature moderate to our sense.

79. Heat has great influence on the *forms* or *states* of bodies. When we heat a solid, it becomes fluid or gaseous; and liquids are

Forms and states of bodies influenced by caloric.

converted into aëriform bodies or vapours. Dr. Black investigated this effect of heat with singular felicity, and his researches rank among the most admirable efforts of experimental philosophy, (Black's *Lectures, edited by John Robison, LL.D.*) During the liquefaction of bodies, a quantity of heat is absorbed, which is essential to the state of fluidity, and which does not increase the sensible or thermometric temperature. Consequently, if a cold solid body, and the same body hot and in a liquid state, be mixed in known proportions, the temperature after mixture will not be the proportional mean, as would be the case if both were liquid, but will fall short of it; much of the heat of the hotter body being consumed in rendering the colder solid, *liquid*, before it produces any effect upon its *sensible temperature*.

80. Equal parts of *water* at 32°, and of *water* at 212° will produce on mixture a mean temperature of 122°. But equal parts of *ice* at 32°, and of water at 212°, will only produce (after the liquefaction of the ice) a temperature of 52°, the greater portion of the heat of the water being employed in thawing the ice, before it can produce any rise of temperature in the mixture. To heat thus *insensible* or *combined*, Dr. Black applied the term *latent heat*. The actual loss of the thermometric heat in these cases was thus estimated; a pound of ice at 32° was put into a pound of water at 172°; the ice melted, and the temperature of the mixture was 32°. Here the water was cooled 140°, while the *temperature* of ice was unaltered; that is, 140° of heat disappeared, their effect being not to increase temperature, but to produce fluidity.

Latent caloric

81. The same phænomena are observable in all cases of liquefaction, and we produce artificial cold, often of great intensity, by the rapid solution of certain saline bodies in water. Upon this principle the action of freezing mixtures depends, some of which may frequently be conveniently and œconomically applied to the purpose of cooling wine or water in hot climates, or where ice cannot be procured. The following Table shews the results of some of Mr. Walker's experiments on this subject.

Table of frigorific mixtures.

Mixtures.	Parts.	Thermometer sinks.
Muriate of ammonia	5	From 50° to 10°
Nitre	5	
Water	16	
Nitrate of ammonia	1	From 50° to 4°
Water	1	
Sulphate of soda	5	From 50° to 3°
Diluted sulphuric acid	4	
Snow	1	From 32° to 0°
Common salt	1	
Muriate of lime	3	From 32° to—50°
Snow	2	
Snow	2	From—10° to—56°
Diluted sulphuric acid	1	
Diluted nitric acid	1	
Snow or pounded ice	12	From—18° to—25°
Common salt	5	
Nitrate of ammonia	5	
Muriate of lime	3	From—40° to—73°
Snow	1	
Diluted sulphuric acid	10	From—68° to—91°
Snow	8	

In order to produce these effects, the salts employed must be fresh crystallized, and newly reduced to a very fine powder. The vessels in which the freezing mixture is made should be very thin, and just large enough to hold it, and the materials should be mixed together as quickly as possible.

Circumstances to be attended to.

In order to produce great cold, they ought to be first reduced to the temperature marked in the table, by placing them in some of the other freezing mixtures; and then they are to be mixed together in a similar freezing mixture.—*Phil. Trans.*, 1795.

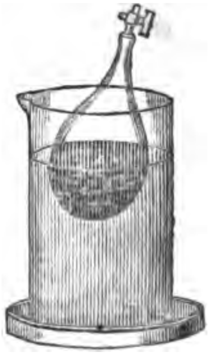
82. When fluids are converted into solids, their latent heat becomes sensible; thus when a solution of Glauber's salt is made suddenly to crystallize (16), its temperature is considerably augmented; and when water is poured upon quicklime, a great degree of heat is produced by the solidification which it suffers in consequence of chemical combination; congelation, therefore, is to surrounding bodies a heating process and liquefaction a cooling process.

Latent calorie made sensible.

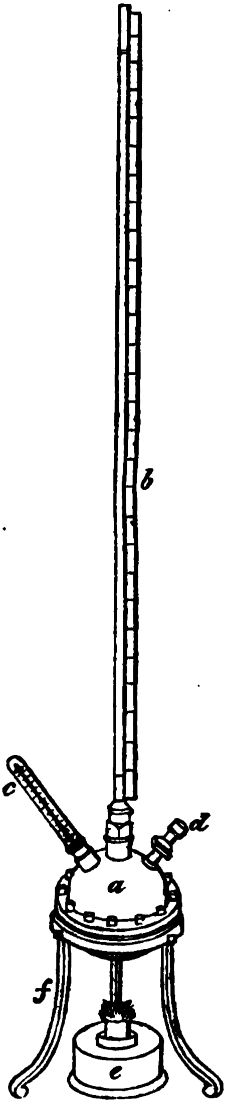
83. When liquids are heated, they acquire the gaseous form, and become invisible elastic fluids, possessed of the mechanical properties of common air. They retain this form or state as long as their temperature remains sufficiently high, but re-assume the liquid form when cooled again. Different fluids pass into the aëriform state at different temperatures, or their boiling points are different; these are also regulated by the density of the atmosphere. *If we diminish atmospheric pressure, we lower the boiling point.* When the barometer is at 28 inches, water will boil at a lower temperature than when it is at 31 inches. Water under mean atmospheric pressure boils at 212°. At the top of Mont Blanc, Saussure found that it boiled at 187°, so that the heights of mountains, and even of buildings, may be calculated by reference to the temperature at which water boils upon their summits. The Reverend Mr. Wollaston has described to the Royal Society the method of constructing a thermometer of extreme delicacy, applicable to these purposes,—*Phil. Trans.*, 1817. In the vacuum of an air-pump, fluids boil at temperatures considerably below their ordinary boiling points.

Altitudes determined by the changes in the boiling points of water.

84. The following apparently paradoxical experiment also illustrates the influence of diminished pressure in facilitating ebullition. Insert a stopcock securely into the neck of a Florence flask, containing a little water, and heat it over a lamp till the water boils, and the steam freely escapes by the open stopcock; then suddenly remove the lamp and close the cock. The water will soon cease to boil; but if plunged into a vessel of cold water ebullition instantly recommences, but ceases if the flask be held near the fire: the vacuum in this case being produced by the condensation of the steam.



Example of diminished pressure facilitating ebullition.



Example of the contrary effect of pressure.

85. Under increased pressure on the contrary, fluids require a higher temperature to produce their ebullition, as may be shown by the following experiments. *a* is a strong brass globe, composed of two hemispheres screwed together with flanches; a portion of quicksilver is introduced into it, and it is then about half filled with water. *b* is a barometer-tube passing through a steam-tight collar, and dipping into the quicksilver at the bottom of the globe. *c* is a thermometer graduated to about 400°, and also passing through an air-tight collar. *d* is a stopcock, and *e* a large spirit lamp. The whole is supported upon the brass frame and stand *f*. Upon applying heat to this vessel, the stopcock being closed as soon as the water boils, it will be found that the temperature of the water and its vapour increases with the pressure, which is measured by the ascent of the mercury in the barometer-tube. The thermometer under atmospheric pressure being at 212°, will be elevated to 217° under a pressure of five inches of mercury, and to 242° under a pressure of 30 inches, or thereabouts; each inch of mercury producing by its pressure a rise of about 1° in the thermometer. The barometer-tube also serves the purpose of a safety-valve, the strength of the brass globe being such as to resist a greater pressure than that of one atmosphere.

Sensible or free caloric made latent.

86. The conversion of a liquid into vapour is always attended with great loss of thermometric heat; and as liquids may be regarded as compounds of solids and heat, so vapours may be considered as consisting of a similar combination of heat with liquids; in other words, a great quantity of heat becomes latent during the formation of vapour. This is easily illustrated by immersing a thermometer into an open vessel of water placed over a lamp. The quicksilver rises to 212°, the water then boils, and although the source of heat remains, neither the water nor the steam acquire a higher temperature than 212°; the heat then becomes latent, and is consumed in the formation of steam.

87. To ascertain the absolute loss of thermometric heat in this case,

Dr. Black instituted the following experiments: he noted the time required to raise a certain quantity of water to its boiling point; he then kept up the same heat till the whole was evaporated, and marked the time consumed by the process; it was thus computed to what height the temperature would have risen, supposing the rise to have gone on above 212°, in the same ratio as below it; and as the temperature of the steam was the same as that of the water, it was fairly inferred that all the heat above 212° was essential to the constitution of aqueous vapour. Dr. Black estimated this quantity at about 810°; that is, the same quantity of heat which is required for the total evaporation of boiling water at 212° would be sufficient to raise the water 810° above its boiling point, or to 1022° had it continued in the liquid state. There are other means of ascertaining the latent heat of steam, which lead us to place it between 900° and 1000°.

Dr. Black's estimate of latent caloric in aqueous vapours.

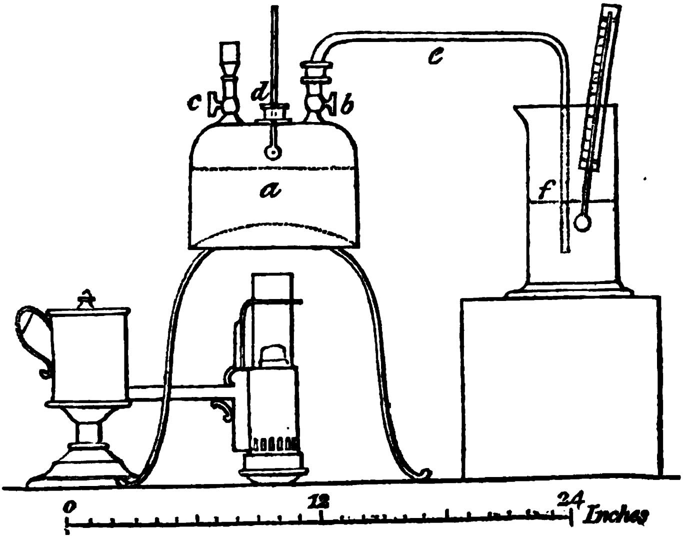
88. The following table of the latent heat of steam and some other vapours is extracted from a paper in the *Philosophical Transactions for* 1818, by Dr. Ure.

Vapour of Water at 212°	967°.00
——— Alcohol	442 .00
——— Ether	302 .38
——— Petroleum	177 .87
——— Oil of Turpentine ..	177 .87
——— Nitric acid	531 .99
——— *Liquid Ammonia* ...	837 .28
——— Vinegar	875 .00

Table of the latent caloric of several fluids by Dr. Ure.

89. When steam is again condensed, or when vapours re-assume the liquid state, their latent heat becomes sensible; and in this way it is obvious that a small quantity of steam will, during its condensation communicate heat sufficient to boil a large quantity of water.

The small boiler, represented in the annexed cut taken from Dr. Henry's *Elements of Chemistry*, may be conveniently employed in experiments on the latent heat of steam.



Dr. Henry's instrument for determining the heating power of condensed steam.

For this purpose the tube *e* must be screwed on the stop-cock *b*, and immersed into the glass of water *f*. The cock *c* being closed, the steam arising from the boiling water *a* will pass into the cold water *f*, the temperature of which will be much augmented by its condensation. Ascertain the increase of temperature and weight, and the result will show how much a given weight of water has had its temperature raised by a certain weight of condensed steam. To another quantity of water, of the same weight and temperature as that in the jar at the outset of the experiment, add a quantity of water at 212°, equal in weight to the condensed steam; it will be found, on comparing the resulting temperatures, that a given weight of steam has produced, by its condensation, a much greater elevation of temperature than the same quantity of boiling water.—Henry, Vol. i. p. 106, 7th edit.

This property taken advantage of in some arts.

90. In breweries and other manufactories, where large quantities of warm and boiling water are consumed, it is frequently heated by thus conveying steam into it, or by suffering steam-pipes to traverse the vessels or by employing double vessels, a plan adopted with particular advantage in the laboratories at Apothecaries Hall. This method of warming water has also been very advantageously applied to heating baths. Where a higher temperature than 212° is required it is necessary to employ steam under adequate pressure, and a very ingenious means of producing high pressure steam for this purpose has been contrived by Messrs. J. and P. Taylor, and applied by them, upon a very large scale, at Whitbread and Co.'s brewhouse.

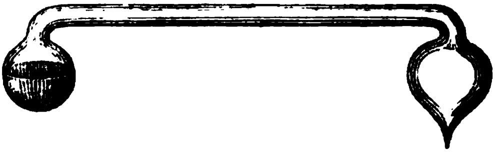
The heat given off by steam during its condensation, is also often advantageously applied to warming buildings, and is at once safe, salubrious, and economical.

Reduction of temperature by evaporation.

91. The cold produced by evaporation is, under certain circumstances, very great. Spirit of wine, and ether, which readily evaporate, produce considerable cold during that process. Upon this principle wine-coolers, and similar porous vessels, refrigerate the fluids they contain; and thus, by accelerating the evaporation of water, by exposing it under an exhausted receiver, containing bodies that quickly absorb its vapour, Professor Leslie has contrived to effect its congelation; the heat required for the conversion of one portion of the water into vapour being taken from the other portion, which is thus reduced to ice. —See *Supplement to Encyclopædia Brit.*, Art. Cold.

92. The instrument invented by Dr. Wollaston, and called by him the *Cryophorus*, acts upon a similar principle. It consists of a glass tube with a bulb at each extremity, of the shape annexed.

Cryophorus of Wollaston.



One of the bulbs is about half filled with with water, and a good vacuum is produced in the other by boiling the water and sealing the tube whilst full of steam. On immersing the empty bulb in a freezing-mixture, the water soon congeals in the other, although the intervening tube be two or three feet long. The vapour in the empty bulb is condensed by the cold, and a fresh quantity of vapour arises successively from the water in the other, by which so much heat is carried off as to cause it to congeal.—*Phil. Trans.* 1813.

93. In many natural operations the conversion of water into vapour, and the condensation of vapour in the form of dew and rain, is a process of the utmost importance, and tends considerably to the equalization of temperature over the globe.

94. Nothing is known of the nature or cause of heat. It has been by some considered as a peculiar fluid, to which the term *Caloric* has been applied; and many phænomena are in favour of the existence of such a fluid. By others, the phænomena above described have been referred to a *vibratory motion* of the particles of matter, varying in velocity with the perceived intensity of the heat. In fluids and gases the particles are conceived to have a motion round their own axes. *Temperature*, therefore, would increase with the velocity of the vibrations; and increase of *capacity* would be produced by the motion being performed in greater space. The loss of temperature, during the change of solids into liquids and gases, would depend upon loss of *vibratory* motion, in consequence of the acquired *rotatory* motion.

Caloric a fluid.

A vibratory motion.

Upon the other hypothesis, *temperature* is referred to the *quantity of caloric* present; and the loss of temperature, which happens when bodies change their state, depends upon the chemical combination of the caloric with the solid in the case of liquefaction, and with the liquid in the case of conversion into the aëriform state.

◆

SECTION IV. *Electricity.*

95. If a piece of sealing-wax and of dry warm flannel be rubbed against each other, they both become capable of attracting and repelling light bodies. A dry and warm sheet of writing-paper, rubbed with India rubber, or a tube of glass rubbed upon silk, exhibit the same phænomena. In these cases the bodies are said to be *electrically excited*; and when in a dark room, they always appear luminous.

Electrical excitement.

96. If two pith-balls be electrified by touching them with the sealing-wax or with the flannel, they repel each other; but if one pith-ball be electrified by the wax, and the other by the flannel, they attract each other. The same applies to the glass and silk: it shows a difference in the electricities of the different bodies, and the experiment leads to the conclusion, that *bodies similarly electrified repel each other, but that when dissimilarly electrified they attract each other.*

Repulsion and attraction.

The term *electrical repulsion* is here used merely to denote the appearance of the phænomenon, the separation being probably referable to the new attractive power which they acquire, when electrified, for the air and other surrounding bodies.

Repulsion.

If one ball be electrified by sealing-wax rubbed by flannel, and another by silk rubbed with glass, those balls will repel each other; which proves that the electricity of the silk is the same as that of the sealing-wax. But if one ball be electrified by the sealing-wax and the other by the glass, they then attract each other, showing that they are oppositely electrified.

These experiments are most conveniently performed with a large downy feather suspended by a silken thread. If an excited glass tube be brought near it, it will receive and retain its electricity; it will be first attracted, and then repelled, and upon re-exciting the tube, and again approaching it, it will not again be attracted, but retain its state of repulsion: but upon approaching it with excited sealing-wax, it will instantly be attracted, and remain in contact with the wax till it has acquired its electricity, when it will be repelled, and in that state of repulsion it will be attracted by the glass. In these experiments care must be taken that the feather remains freely suspended in the air, and touches nothing capable of carrying off its electricity.

Franklin's theory.

97. The terms *vitreous* and *resinous* electricity were applied to these two phænomena; but Franklin, observing that the same electricity was not inherent in the same body, but that glass sometimes exhibited the same phænomena as wax, and *vice versâ*, adopted another term, and, instead of regarding the phænomena as dependent upon two electric fluids, referred them to the presence of one fluid, in excess in some cases, and in deficiency in others. To represent these states he used the terms *plus* and *minus*, *positive* and *negative*. When glass is rubbed with silk, a portion of electricity leaves the silk and enters the glass; it becomes *positive*, therefore, and the silk *negative*; but when sealing-wax is rubbed with flannel, the wax loses and the flannel gains; the former, therefore, is negative, and the latter positive. All bodies in nature are thus regarded as containing the electric fluid, and when its equilibrium is disturbed, they exhibit the phænomena just described.

98. The substances enumerated in the following table become positively electrified when rubbed with those which follow them in the list, but with those which precede them they become negatively electrical. —Biot, *Traité de Physique*, tom. ii., p. 220.

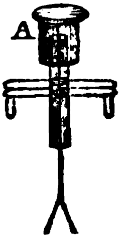
Cat's skin
Polished glass
Woollen cloth
Feathers
Paper
Silk
Gum lac
Rough glass.

Electrometer.

99. Very delicate pith-balls, or strips of gold leaf, are usually employed in ascertaining the presence of electricity; and, by the way in which their divergence is affected by glass or sealing wax, the kind or state of electricity is judged of. When properly suspended or mounted for delicate experiments, they form an *electrometer* or *electroscope*. For this purpose the slips of gold leaf are suspended by a brass cap and wire in a glass cylinder; they hang in contact when unelectrified; but when electrified they diverge, as in the marginal woodcut.

Singer's improvement.

When this instrument, as usually constructed, becomes in a small degree damp, its delicacy is much diminished, and it is rendered nearly useless. The following improvement in its construction by the late Mr. Singer renders it a much more sensible and useful instrument. It is constructed as usual, with a glass cylinder, surmounted by a brass cap; but the insulation is made to depend upon a glass tube, about four inches long, and one-fourth of an inch internal diameter, covered both on the inside and outside with sealing-wax, and having a brass wire of a sixteenth or twelfth of an inch thick and five inches long, passing through its axis, so as to be perfectly free from contact with any part of the tube, in the middle of which it is fixed by a plug of silk which keeps it concentric with the internal diameter of the tube. A, is a brass cap screwed upon the upper part of this wire; it serves to limit the atmosphere from free contact with the outside of the tube, and also defends its inside from dust; to the lower part of the wire the gold leaves are attached, and the whole mounted as usual, and as represented above.

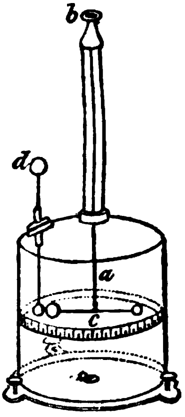


Method of determining the kind of electricity.

100. The kind of electricity by which the gold leaves are diverged may be judged of by approaching the cap of the instrument with a stick of excited sealing-wax; *if it be negative* the divergence will increase; *if positive*, the leaves will collapse, upon the principle of the mutual annihilation of the opposite electricities, or that bodies similarly electrified repel each other, but that when dissimilarly electrified they become mutually attractive. (96.)

Coulomb's electrical balance.

101. To ascertain the actual repulsive and attractive powers appertaining to weakly-electrified bodies, M. Coulomb has ingeniously availed himself of the principle of torsion, and has thus constructed his *electrical balance*. It consists of a fine metallic wire, *a*, one end of which is attached to the screw *b*, and to the other is suspended the horizontal needle *c*, composed of gum-lac or other nonconductor, and armed at one extremity with a gilt pith-ball, counterpoised at the other end by an index. The conductor *d*, is a small wire with a ball at each end passing through the glass receiver in which the needle is suspended, and having its lower ball opposed to that of the needle. By the screw *b*, the two balls are brought into contact, and the index then points to *o*, on the divided scale of degrees. On communicating a very feeble electrical power to the conductor, it transfers it to the moveable pith-ball, and repels it a certain number of degrees, proportional to the intensity of the acquired electricity, and measured by the power of torsion which it exerts upon the fine wire. By experiments made with this electrometer, it would appear that the electrical powers follow the law of gravitation, in being in the inverse ratio of the squares of the distances of the acting bodies. In the most delicate construction of the instrument a single silk-worm's thread is used instead of the wire.



Electrical powers are inversely as the squares of their distances i. e. similar to the powers of gravitation.

102. Some bodies suffer electricity to pass through their substance, and are called *conductors*. Others only receive it upon the spot touched, and are called *nonconductors*. The former do not, in general become electric by friction, and are called *nonelectrics:* the latter, on the contrary, are *electrics*, or acquire electricity by friction. They are also called *insulators*. The metals are all conductors; dry air, glass, sulphur, and resins, are nonconductors. Water, damp wood, spirit of wine, damp air, and some oils, are imperfect conductors.

Conductors & nonconductors.

103. Rarefied air admits of the passage of electricity; so does the Torricellian vacuum: hence if an electrified body be placed under the receiver of the air-pump, it loses its electricity during exhaustion. So that the air, independent of its nonconducting power, appears to influence the retentive properties of bodies in respect to electricity, by its pressure.

Electricity passes through rarefied air or a vacuum.

104. There appears to be no constant relation between the state of bodies and their conducting powers: among solids, metals are conductors, but gums and resins are nonconductors; among liquids, strong alcaline, acid, and saline solutions, are good conductors; pure water is an imperfect conductor, and oils are nonconductors; solid wax is almost a nonconductor, but when melted, a good one. Conducting powers belong to bodies in the most opposite states; thus the flame of alcohol, and ice, are equally good conductors. (BIOT, *Traité de Physique*, tom. ii., p. 213.) Glass is a nonconductor when cold, but conducts when red-hot; the diamond is a nonconductor, but pure and well-burned charcoal is among the best conductors.

No constant relation between the state of bodies and their conducting powers.

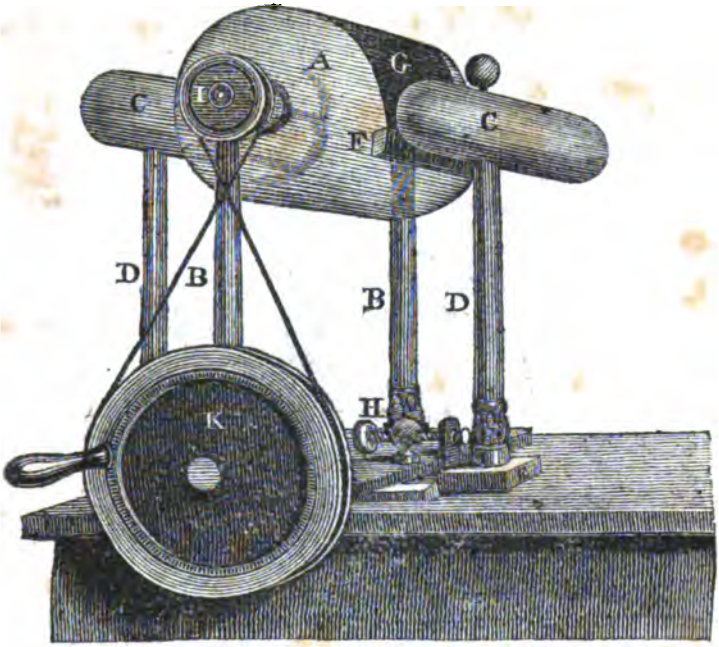
105. There are many mineral substances which show signs of electricity when heated, as the tourmalin, topaz, diamond, boracite, &c.; and in these bodies the different surfaces exhibit different electrical states.

Some substances become electric by being heated.

106. Whenever one part of a body, or system of bodies, is positive, another part is invariably negative; and these opposite electrical states are always such as exactly to neutralize each other. Thus, in the common electrical machine, one conductor receives the electricity of of the glass cylinder, and the other that of the silk rubber, and the former conductor is positive and the latter negative; but if they be connected, all electrical phænomena cease.

Opposite electricities at opposite sides of a body.

107. The best electrical machine for experimental purposes is represented in the annexed sketch.



Electrical machine.

Description.

It consists of a glass cylinder A about 10 or 12 inches in diameter, and 15 to 20 inches in length, turning between two upright pillars of glass, B B, fixed to a stout mahogany base. Two smooth metal conductors, equal in length to the cylinder, and about one-third of its diameter, C C, are placed parallel to it upon two glass pillars, D D, which are cemented into two sliding pieces of wood E, by which their distance from the cylinder may be adjusted. One of the conductors has a cushion, F, attached to it by a bent metallic spring, nearly as long as the cylinder, and about one inch or an inch and a half wide, to the upper part of which is sewed a flap of oil-silk, G, which should reach from the cushion over the upper surface of the glass cylinder, to within about an inch of a row of points attached to the side of the opposite conductor. The conductor to which the cushion is attached is called the negative conductor; the other collects the electricity of the glass, and is called the positive conductor. H, is an adjusting screw to regulate the pressure of the cushion upon the cylinder. The motion of the cylinder is in the direction of the silk flap, and may be communicated by a handle attached at I, or by the multiplying wheel K. To put this electrical machine into good action, every part should be made perfectly clean and dry. The cushion is then anointed with amalgam, and applied by a gentle pressure to the cylinder. If positive electricity is required, it may be received from the conductor bearing the points, that supporting the cushion being uninsulated by a wire passing from it to the stand;—if, on the contrary, negative electricity is required, it may be obtained from the insulated cushion cylinder, the other being uninsulated.

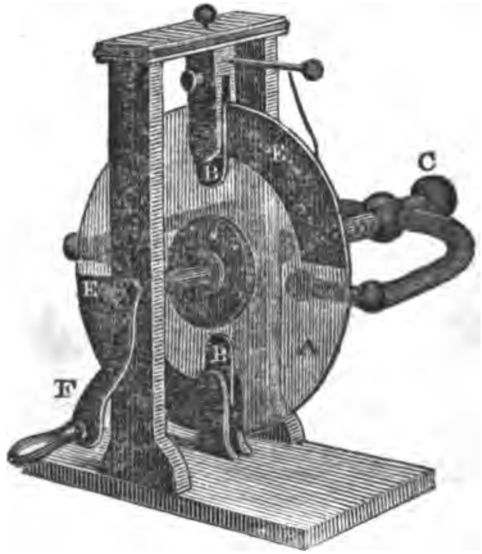
Method of using it.

Amalgam for exciting electricity.

108. The best *amalgam* is composed of one part of tin and two of zinc melted together, and mixed, while fluid, with six parts of hot mercury in an iron mortar. This mixture is triturated till it becomes a fine powder, which is then formed into a tenacious paste with hogs' lard.

Another form of electrical machine

109. Another form of the electrical machine consists of a circular glass plate A, mounted upon an axis and rubbed by two pairs of cushions, as shewn at B B. The brass conductor C has its points opposed to the plate, and is insulated by the glass stem D.—E E are double pieces of oil-silk passing from the cushions to near the points. The whole is supported by a stout mahogany frame, and motion is given to the plate by the winch F.



Description.

Advantages & vice versa.

These electrical machines have considerable power; they are easily cleaned and excited, and are more portable than the cylinders; but as they cannot be conveniently insulated, the negative electrical power cannot be well exhibited, so that for the purposes of experimental research the former machines are preferable.

Phænomena observed in using these machines.

110. When the electrical machine is in good order, and the atmosphere dry, it produces a crackling noise when the plate or cylinder is turned, and flashes and sparks of light are seen upon various parts of the glass passing from the cushion to the conductor: if the knuckle be held near the conductor, sparks pass to it through some inches of air, with a peculiar noise, and excite slightly painful sensation in the part upon which they are received. It is conjectured that the cause of the light thus perceived, is the sudden compression of the air or medium through which the electricity passes, and it is always probably attended by a proportionate elevation of temperature, as is shown by the power of the spark to inflame spirit of wine, fulminating silver, and other easily inflammable compounds.

Effect of a change, in the density of a medium upon electric light.

111. The appearance of the electric light is modified by the density of the medium through which it passes. In dense air it is bright and white; in rarefied air it is of a reddish tinge and faint and divided;

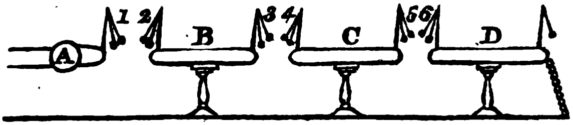
and in the more perfect vacuum of a good air-pump, it is of a purplish hue, and scarcely visible except in a very dark room.

112. If an insulated conductor be electrified, and an uninsulated conductor be opposed to it, there being between the two a thin stratum of air, glass, or other nonconductor, the uninsulated conductor, under such circumstances, acquires an opposite electrical state to that of the originally electrified insulated conductor. In this case, the uninsulated body is said to be electrified by *induction* and the induced electricity remains evident, until an explosion, spark, or discharge happens, when the opposite electricities annihilate each other. Induced electricity may thus be exhibited through a long series of insulated conductors, provided the last of the series be communicated with the earth.

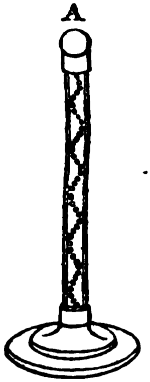
Electricity by induction.

Thus, in the following diagram, A, may represent the positive conductor of the electrical machine; B, C, and D, three insulated conductors, placed at a little distance from each other, D having a chain touching the ground; then the balls 1, being positive, will attract the balls 2, which are rendered negative by induction. Under these circumstances, each of the conductors becomes polar, and the balls 3 are positive, while 4 are negative, 5 positive, 6 negative, *&c.*: the central points of the conductors, B C D, are neutral. When these opposite electrical states have arrived at a certain intensity, sparks pass between the different conductors, and the electrical phænomena cease.

Illustration.

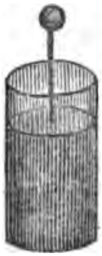


113. The extent of such a polar arrangement may be greatly increased by pasting small spangles of tinfoil, upon a clean plate of glass, within a small distance of each other, each of which will then represent an insulated conductor; and the first spangle being held near the excited conductor of the machine, and the last in the hand, a series of brilliant sparks will pass between each, indicating the annihilation of the opposite electrical states. The *spiral luminous tube*, A, luminous words, flowers, &c., are arrangements of this kind.



Spiral luminous tube.

114. Upon the principle of induction it is that the accumulation of electricity in the *Leyden phial* is effected. It consists of a thin glass jar, coated internally and externally with tinfoil to within a short distance of its mouth. When the inner surface is rendered positive by union with the conductor of the electrical machine, the exterior, being connected with the ground, becomes negative by induction. When the inner and outer surfaces are united by a conductor, all electrical accumulation is annihilated by a powerful spark, and the two opposite states are found to have been precisely equivalent.



Leyden phial.

If the communication between the opposite surfaces of the Leyden phial be made by the hands, a painful jarring sensation is felt at the joints of the fingers, the elbows shoulders, and chest, commonly called the *electrical shock.* Metallic wires, with balls at their ends, bent or jointed and fixed to a glass handle, are generally used to transfer the electric charge, and these instruments are called *dischargers.*

Electrical wind or coldness.

115. In all cases of electrical accumulation, the surfaces intended to retain it must be free from asperities, and points: a pointed wire held near the prime conductor instantly gains an opposite state, and rapidly discharges it; if it be affixed to the conductor, a similar effect is observed; and upon holding the hand near the point, a peculiar coldness is perceived, which has been called the *electrical aura*, and which depends upon the rapid recession of the electrified air. If the Leyden jar be discharged by a pointed wire, the electricities quietly annihilate each other, and no explosion can be produced.

Henly's electrometer.

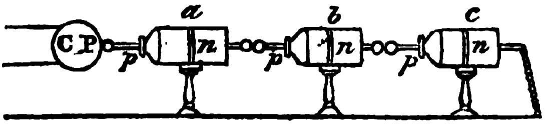
116. To ascertain the relative *charge* which the jar has received, we employ the *quadrant electrometer*, contrived by Henly. It consists of a rounded stem of metal, A to the side of which is attached an ivory semi-circle, B; to the centre is affixed a pin, upon which a very thin piece of cane or ivory, about 4 inches long, with a pith ball at its lower extremity, turns freely, traversing the semicircle as an index. The lower half of the semi-circle is divided into 90°. When not electrified, its index hangs parallel to the stem at 0°, but when electrified, the ball recedes and carries the index over the graduated circle to a greater or less extent, in proportion to the intensity of the electricity.

Experiment to shew the annihilation of opposite electricities.

117. The annihilation of positive by negative electricity, and *vice versâ*, may be well shown by the following experiment. Attach Henly's quadrant electrometer to the knob of a Leyden jar, and give it a certain charge from the positive conductor: then transfer the jar to the negative conductor, and whilst receiving a negative charge, the electrometer will fall, indicating the loss of all electrical accumulation; it then will again rise as the jar becomes negatively charged, and may again be discharged by transferring it to the positive conductor.

Connection of Leyden jars.

118. If one Leyden jar be insulated with its internal surface connected with the positive conductor, another jar may be charged from its exterior coating; and if this second jar be insulated, a third may be charged from its exterior coating, and so on for any number of jars, provided always that the exterior coating of the last jar be connected with the ground. In this case, a polar arrangement, similar to that of the conductors just described, (112) will have been formed, glass being the medium of induction instead of air.



Let c P be the positive conductor of the electrical machine, and *a b c* three insulated Leyden phials, the outer coating of *c* being connected with the ground; it is then obvious, that there will be the same polar state as in the conductors just noticed; that the insides of *a*, *b*, and *c*, will be positive, and the outsides negative; and that, consequently, on removing the jars from each other, they will all be similarly charged, and that if the three inner surfaces *p p p* and the outer surfaces *n n n* be united, the whole may be discharged as one jar.

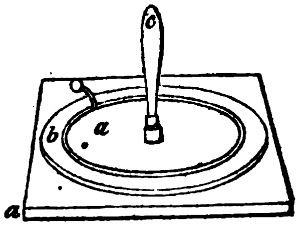
119. Upon this principle a jar may be charged by the transfer of its inherent electricity from one surface to the other, by insulating it and connecting its interior coating with the positive conductor, and its exterior with the negative;—thus the electricity received by the former is withdrawn from the latter, and the jar becomes charged. This experiment well illustrates the non conducting power of glass.

Use of the metallic coatings of the Leyden jar.

120. The use of the metallic coatings of the Leyden phial is equally to distribute the electricities over the opposite surfaces, for if the coatings be made moveable the jar remains charged when they are removed. In discharging the jar, too, the annihilation is rendered simultaneous by the conducting coating suffering the transfer of the opposite electricities from every part of the glass surfaces at the same instant.

121. There are some other electrical instruments (the operation of which is referable to the phænomena of *induction*, such as the electrophorus, and the condenser.

The *electrophorus* consists of two metallic plates, *a a*, with an intervening plate of resinous matter, *b*, for which equal parts of shell-lac, resin, and Venice turpentine, are generally used, the mixture being carefully melted in a pipkin, and poured, whilst liquid, into a wooden or metal hoop, of a proper size, placed upon a polished surface of glass or marble, from which it easily separates when cold; it should be about half an inch thick, and the smooth surface being uppermost the lower side should be covered with tin foil, or attached to any other metallic plate; a polished brass plate, with a glass handle *c* attached to it, is then placed upon the upper surface of the resinous plate, and of rather smaller diameter. The resin is then to be excited with a piece of dry fur, and the instrument will be found to exhibit the following phænomena:



Electrophorus

Mode of using it.

Upon raising the brass plate by its insulating handle, it will be found very feebly electrical; replace it, touch it with the finger and again lift it off by its handle, and it will give a spark of positive electricity. This process may very often be repeated without fresh excitation, which circumstance, as well as the nature of the electrical charge, shows that the electricity of the moveable brass plate is not directly derived from the resin, but that it depends upon induction: this is more obvious by considering the upper plate, not as in contact with but merely very near the resinous disc, which from the minute irregularities upon its surface, is really the case; the negative electricity, therefore, of the excited resinous plate is communicated from a few points of contact to the brass plate, upon its first application, and then the latter is precisely in the state of a conductor opposed to, but not touching, an electrified surface, and consequently in due condition to be rendered electrical by induction, when occasionally uninsulated by the contact of the finger.

A phenomenon of induction, well shown by this instrument.

With this instrument, one phænomenon of induction may be shown, which cannot be so well exhibited by any other; namely, the increased capacity for electricity of the conductor under the influence of induction. The brass plate, when placed upon the resin, may be regarded as in a polar state; the lower surface next the resin being positive, the upper surface being negative. Upon touching the upper surface with the finger, it instantly acquires electricity, loses its polarity, and becomes positive, giving, upon removal, a positive spark to any conductor. That the quantity of electricity received from the finger, or other source, is equivalent to that given out, is shown by the following experiment: Place the metallic upon the resinous plate, and touch the former with the knob of a Leyden phial; then touch the cap of an electrometer with the knob of the phial, and it will give a certain negative divergence to the leaves; raise the plate and present the knob of the jar to it, a spark will pass; and upon applying the jar a second time to the electrometer, the leaves will entirely collapse, showing the exact annihilation of the former negative, by the latter positive charge.

When the electrophorus is placed upon an insulating stand, its lower plate is always found in an opposite electrical state to the upper one, so that in this respect it resembles the coatings of a Leyden jar.

The electrophorus used as an electrical machine.

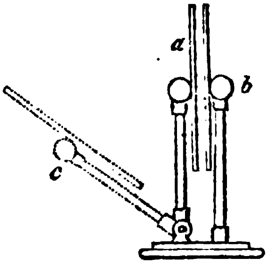
The electrophorus may often be used for the same purposes as the electrical machine, and in the laboratory it furnishes a very convenient substitute for that more expensive piece of apparatus.

Singular Phenomenon connected with induction.

122. When an insulated surface is opposed to another which is not insulated, so as to be affected by it by induction, the electricity communicated to the former suffers a singular increase of tension or intensity on breaking the induction by removing the opposed uninsulated conductor; this property is strikingly exhibited in the following experiment:—Provide a brass plate, 3 or 4, inches in diameter, and drop upon its lower surface three small spots of sealing-wax; place it upon a similar plate, forming the cap of the gold leaf electrometer, from which it will be separated about a twentieth of an inch by the three small insulating legs of wax. Connect the upper plate with the ground by touching it, and give a very feeble electrical charge to the electrometer, so as scarcely perceptibly to diverge its leaves; then suddenly remove the upper plate, by which the induction will be broken, and the tension of the electricity suddenly increased, so as to cause a very considerable divergence of the leaves.

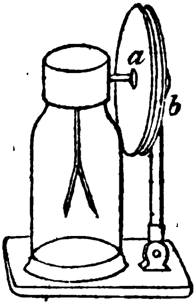
Condensers.

The plates employed in this experiment have been called *condensers.* They are sometimes placed perpendicularly, and the uninsulated plate *a* is supported by a wire and joint, so as to be brought as close as possible to the insulated plate *b*, without touching; the latter is in communication with the electrometer, and having received its charge, the moveable uninsulated plate is drawn back, as in *c*, and the intensity of the electricity displayed.



Different arrangement of the condensers.

Sometimes the condenser is directly attached to the electrometer, as shown in the annexed cut.—*a*, the insulated plate; *b*, the moveable plate in communication with the ground.



Various attempts have been made so to combine electrical condensers, as to multiply their effect, and render very slight electrical changes susceptible of measurement and examination; of this nature is the *Electrical Multiplier*, contrived by Mr. Cavallo, (*Complete Treatise on Electricity*, Vol. iii. p. 99;) the *Doublers* of Mr. Bennet and Mr. Nicholson, (*Phil. Trans.* lxxvii. and lxxviii.) and Mr. Wilson's *Double Multiplier*, (Nicholson's *Journal*, ix;) but the complexity of these instruments, as Mr. Singer has remarked, renders their results equivocal, and often has a tendency to produce the electrical states, independent of the intended source, or to change that originally communicated.

Quantity & intensity of electric power.

123. Electricians generally employ the term *quantity* to indicate the absolute quantity of electric power in any body, and the term *intensity* to signify its power of passing through a certain stratum of air or other ill-conducting medium.

Illustration.

If we suppose a charged Leyden phial to furnish a spark, when discharged, of one inch in length, we should find that another uncharged Leyden phial, the inner and outer coating of which were communicated with those of the former, would upon the same quantity of electricity being thrown in, reduce the length of the spark to half an inch; here, the *quantity* of electricity remaining the same, its *intensity* is diminished by one-half, by its distribution over the larger surface.

124. It is obvious, that the extension of surface alluded to in the last paragraph, will be attended with a greater superficial exposure to the unelectrified air; and hence it might be expected, that a similar diminution of intensity would result from the vicinity of the electrified surface to the ground, or to any other body of sufficient magnitude in its ordinary state. That this is the case, may be shown by diverging the leaves of the gold-leaf electrometer, and in that state approaching the instrument with an uninsulated plate, which, when within half an inch of the electrometer plate, will cause the leaves to collapse; but on removing the uninsulated plate, they will again diverge, in consequence of the electricity regaining its former intensity. The same fact is shown by the condensing electrometer.

Power of the Leyden jar in proportion to its surface.

125. The power of the Leyden jar is proportioned to its surface, but a very large jar is inconvenient and difficult to procure; the same end is attained by arranging several jars, so that by a communication existing between all their interior coatings, their exterior being also united, they may be charged and discharged as one jar. Such a combination is called an electrical *Battery*, and is useful for exhibiting the effect of accumulated electricity.

Electrical Battery.

Its discharge attended with report can prove fatal to animal life.
produces combustion, &c.

The discharge of the battery is attended by a considerable report, and if it be passed through small animals it instantly kills them; if through fine metallic wires, they are ignited, melted, and burned; and gunpowder, cotton sprinkled with powdered resin, and a variety of other combustibles, may be inflamed by the same means.

Other sources of electricity.

126. There are many other sources of electricity than those just noticed. When glass is rubbed by mercury, it becomes electrified, and this is the cause of the luminous appearance observed when a barometer is agitated in a dark room, in which case flashes of light are seen to traverse the empty part of the tube. Even the friction of air upon glass is attended by electrical excitation: for Mr. Wilson found that by blowing upon a dry plate of glass with a pair of bellows, it acquired positive electricity. Whenever bodies change their forms, their electrical states are also altered. Thus the conversion of water into vapour, and the congelation of melted resins and sulphur, are processes in which electricity is also rendered sensible.

127. When an insulated plate of zinc is brought into contact with one of copper or silver, it is found, after removal, to be positively electrical, and the silver or copper is left in the opposite state.

Of two metals properly connected the most oxidizable one is always positive.

The most oxidizable metal is always positive, in relation to the least oxidizable metal, which is negative, and the more opposite the metals in these respects, the greater the electrical excitation; and if the metals be placed in the following order, each will become positive by the contact of that which precedes it, and negative by the contact of that which follows it; and the greatest effect will result from the contact of the most distant metals.

Metallic arrangement for electric excitation.

Platinum.
Gold.
Silver.
Mercury.
Copper.
Iron.
Tin.
Lead.
Zinc.

Electricity conducted by nerves.

If the nerve of a recently killed frog be attached to a silver probe, and a piece of zinc be brought into the contact of the muscular parts of the animal, violent convulsions are produced every time the metals thus connected are made to touch each other; exactly the same effect is produced by an electric spark, or the discharge of a very small Leyden phial.

If a piece of zinc be placed upon the tongue, and a piece of silver under it, a peculiar sensation will be perceived every time the two metals are made to touch.

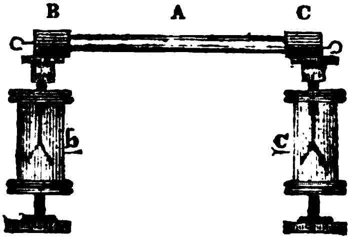
Chemical action accompanying that of electricity.

128. In these cases the chemical properties of the metals are observed to be affected. If a silver and a zinc wire be put into a wine glass full of dilute sulphuric acid, the zinc wire only will evolve gas; but upon bringing the two wires in contact with each other, the silver will also copiously produce air bubbles.

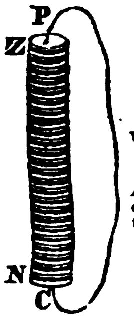
Electric column.

129. If a number of alternations be made of copper or silver leaf, zinc leaf, and thin paper, the electricity excited by the contact of the metals will be rendered evident to the common electrometer.—A represents a glass tube, in which are regularly arranged a number of alternating plates of silver, zinc, and thin paper, forming DE LUC's *electrical column.* The metallic cap B is in contact with the silver plate, and C with the zinc plate, at the respective extremities of the pile. Upon examining

the electrometers, it will be found that *b* is negatively diverged, and *c* positively.



De Luc's column.

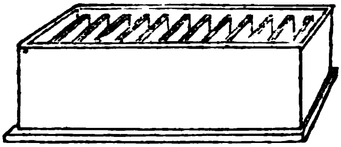


130. If the same arrangement be made with the paper moistened with brine, or a weak acid, it will be found on bringing a wire communicating with the last copper plate into contact with the first zinc plate, that a spark is perceptible, and also a slight shock, provided the number of alternations be sufficiently numerous. This is the Voltaic apparatus.

Volta's.

131. Several modes of constructing this apparatus have been adopted, with a view to render it more convenient or active. Sometimes double plates of copper and zinc soldered together, are cemented into wooden troughs in regular order, the intervening cells being filled with water, or saline or acid solutions.

Another mode of constructing the apparatus.



132. Another form consists in arranging a row of glasses, containing dilute sulphuric acid, in each of which is placed a wire or plate of silver or copper, and one of zinc, not touching each other, but so connected by metallic wires, that the zinc of the first cup may communicate with the copper of the second; the zinc of the second with the copper of the third, and so on throughout the series, as represented in the annexed cuts.

Coronne de tasse an other variety of form.

Fig. 1.

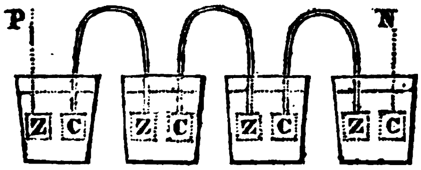
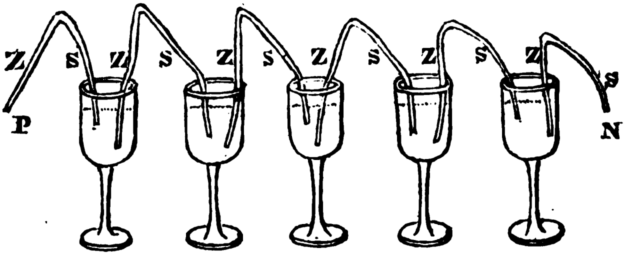


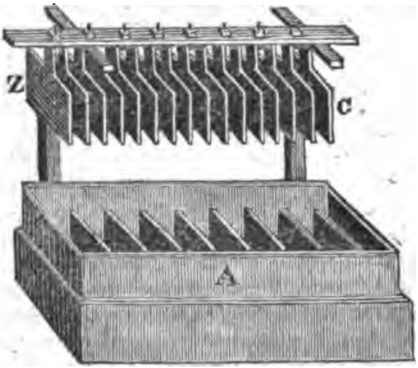
FIG. 2.



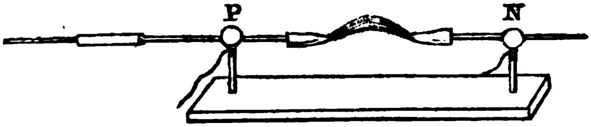
By applying the moistened fingers to the extreme wires P and N, a shock will be felt; and on making a communication between them by a wire, it will be found that the copper plates in Fig. 1, and the silver wires in Fig. 2, instantly acquire the power of decomposing the dilute sulphuric acid, and that the chemical action of the zinc is much augmented. One advantage of this arrangement over the former (131) is, that both surfaces of the metal are exposed; whereas in the other, by soldering the plates together, its action is diminished.

The most approved construction.

133. In the following sketch, the trough A is made of earthenware, with partitions of the same material, and the metallic plates are attached to a bar of wood, arranged as in Fig. 1, so that they can be immersed and removed at one operation. The troughs are filled with dilute acid, and by uniting them in regular order, the apparatus may be enlarged to any extent. This is, on the whole, the best form of the Voltaic instrument hitherto devised, and it is thus that the great apparatus of the Royal Institution is constructed.



134. When from 500 to 1000 double plates are thus arranged and rendered active by immersion into a liquid consisting of about sixty parts of water with one of nitric and one of sulphuric acid, very brilliant effects are produced when the opposite poles are properly united by conductors. Thus, if a piece of charcoal united with the negative wire be made to touch another piece united with the positive wire, a bright spark and intense ignition ensue, and by slowly withdrawing the points from each other a constant current of electricity takes place through the heated air, producing a magnificent arc of intense light, in the form here represented.



Galvanic combustion of charcoal.

Combustion and fusion of metals.

135. When the metals and other inflammable bodies are placed in this arc of fire they burn with great brilliancy, and those which are most difficult of fusion give evidence of the intensity of the heat by instantly melting; and some earthy and other bodies infusible by ordinary methods are liquefied by the same means. The shock is painful and dangerous. When the communication between the points of charcoal is made in rarefied air, the annihilation of the opposite electricities takes place at some inches' distance, producing a stream of deep purple light.

Magnetism resulting from galvanism.

136. When the poles of the Voltaic apparatus are connected by a steel wire, it acquires magnetic properties; and if by a platinum or other metallic wire, that wire exhibits numerous magnetic poles, which attract and repel the common magnetic needle. This very curious fact was first observed by Professor Oersted, of Copenhagen.

Decomposition of water.

137. On immersing the wires from the extremes of this apparatus into water, it is found that the fluid suffers decomposition, and that oxygen gas is liberated at the positive wire or pole, and hydrogen gas at the negative pole.

Combustible constituents, join in the negative pole.

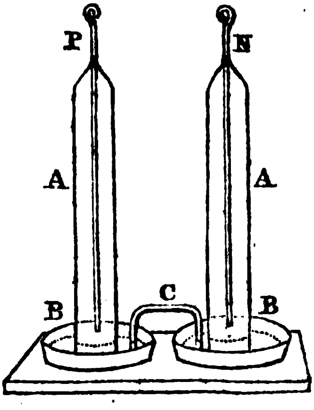
Explanation.

Supporters of combustion are attracted to the positive pole.

All other substances are decomposed with similar phænomena, the inflammable element being disengaged at the negatively electrical surface; hence it would appear, upon the principle of similarly electrified bodies repelling each other, and dissimilarly electrified bodies attracting each other, (96) that the inherent or natural electrical state of the inflammable substances is *positive*, for they are attracted by the negative or oppositely electrified pole; while the bodies, called supporters of combustion, or acidifying principles, are attracted by the positive pole, and, therefore, may be considered as possessed of the *negative* power.

Chemical union destroyed by galvanism.

138. When bodies are thus under the influence of electrical decomposition, their usual chemical energies are suspended, and some very curious phænomena are observed, which may be illustrated by the following experiments.



Apparatus for illustrating this power.

Fill the glass tubes A A, which are closed at top and open at bottom, with infusion of violets, or red cabbage, and invert them in the basins B B, containing a solution of Glauber's salt, and connected by the glass tube C, also containing the blue infusion. P and N are platinum wires, which pass into the tubes nearly to the bottom, and which are to be connected with the positive and negative extremities of the Voltaic apparatus. It will be found that oxygen is evolved at the wire P, and hydrogen at N, derived from the decomposition of the water. The

Glauber's salt, which consists of sulphuric acid and soda, will also be decomposed; and the blue liquor will be rendered red in the positive vessel, by the accumulation of sulphuric acid, and green in the negative, by the soda, while the acid and alcali will each traverse the tube c without uniting, in consequence of being under the influence of electrical attraction.

139. The most difficultly decomposable compounds may be thus resolved into their component parts by the electrical agency; by a weak power the proximate elements are separated, and by a stronger power these are resolved into their ultimate constituents. (51).

Davy's idea of the connection between chemical attraction & galvanism.

140. All bodies which exert powerful chemical agencies upon each other when freedom of motion is given to their particles, render each other oppositely electrical when acting as masses. Hence Sir H. Davy, the great and successful investigator of this branch of chemical philosophy, has supposed that electrical and chemical phænomena, though in themselves quite distinct, may be dependent upon one and the same power, acting in the former case upon masses of matter in the other upon its particles.

Circumstances promoting the power of the voltaic apparatus.

141. The power of the Voltaic apparatus to communicate divergence to the electrometer, is most observed when it is well insulated and filled with pure water; but its power of producing ignition and of giving shocks, and of producing the other effects observed when its poles are connected, are much augmented by the interposition of dilute acids, which act chemically upon one of the plates: here, the insulation is interfered with by the production of vapour, but the quantity of electricity is much increased, a circumstance which may, perhaps be referred to the increase of the positive energy of the most oxidable metal by the contact of the acid. In experiments made with the great battery of the Royal Institution, it has been found that 120 plates rendered active by a mixture of one part of nitric acid and three of water, produced effects equal to 480 plates rendered active by one part of nitric acid and fifteen of water.

Arrangement for intensity for quantity.

142. In the Voltaic pile, the *intensity* of the electricity increases with the number of alternations, but the *quantity* is increased by extending the surface of the plates. Thus, if a battery, composed of thirty pairs of plates two inches square, be compared with another battery of thirty pairs of twelve inches square, charged in the same way, no difference will be perceived in their effects upon bad or imperfect conductors; their powers of decomposing water and of giving shocks will be similar; but upon good conductors the effects of the large plates will be considerably greater than those of the small: they will ignite and fuse large quantities of platinum wire, and produce a very brilliant spark between charcoal points. The following experiment well illustrates the different effects of quantity and intensity in the Voltaic apparatus.

Experimental illustration.

Immerse the platinum wires connected with the extremity of a charged battery composed of twelve-inch plates into water, and it will be found that the evolution of gas is nearly the same as that occasioned by a similar number of two-inch plates. Apply the moistened fingers to the wires, and the shock will be the same as if there were no connexion by the water. While the circuit exists through the human body and the water, let a wire attached to a thin slip of charcoal be made to connect the poles of the battery, and the charcoal will become vividly ignited. The water and the animal substance discharge the electricity of a surface probably not superior to their own surface of contact with the metals; the wires discharge all the residual electricity of the plates; and if a similar experiment be made on plates of an inch square, there will scarcely be any sensation when the hands are made to connect the ends of the battery, a circuit being previously made through water; and no spark, when charcoal is made the medium of connexion, imperfect conductors having been previously applied.

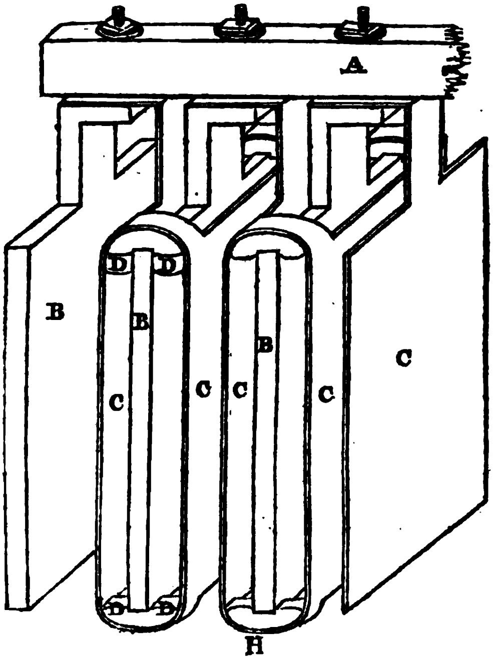
Children's battery.

These relative effects of quantity and intensity were admirably illustrated by the experiments instituted by Mr. Children, who constructed a battery, the plates of which were two feet eight inches wide, and six feet high. They were fastened to a beam suspended by counterpoises from the ceiling of his laboratory, so as to be easily immersed into or withdrawn from the cells of acid. The effects upon metallic wires and perfect conductors were extremely intense; but upon imperfect conductors, such as the human body, and water, they were feeble.—*Phil. Trans.*, 1815, p. 363.

Metallic fusion.

143. When the extremes of a battery composed of large plates are united by wires of different metals, it is found that some are more easily ignited than others, a circumstance which has been referred to their conducting powers: thus, platinum is more easily ignited than silver, and silver than zinc. If the ignition be supposed to result from resistance to the passage of electricity, we should say that the zinc conducted better than silver, and the silver than platinum.

144. An important improvement has been suggested in the construction of the Voltaic apparatus by Dr. Wollaston, (*Annals of Philosophy*, Sept. 1815,) by which great increase of *quantity* is obtained without inconvenient augmentation of the size of the plates: it consists in extending the copper plate, so as to oppose it to every surface of the



Wollaston's improvement.

zinc, as seen in the annexed cut. A is the rod of wood to which the plates are screwed; BB the zinc plates connected as usual with the copper plates CC, which are doubled over the zinc plates, and opposed to them upon all sides, contact of the surfaces being prevented by pieces of wood or cork placed at DD.

The most economical & useful form.. With a single pair of plates of very small dimensions constructed upon this principle, Dr. Wollaston succeeded in fusing and igniting a fine platinum wire. From the experience which I have had of this construction, I am inclined to consider it the most œconomical and useful form of the Voltaic apparatus; certainly, at least, it is so for all those researches in which there is an occasional demand for quantity as well as intensity of electricity.

Voltaic pile operates upon the principle of induction. 145. The theory of the Voltaic pile is involved in many difficulties. The original source of electricity appears to depend upon the contact of the metals, for we know that a plate of silver and a plate of zinc, or of any other difficultly and easily oxidable metals, become negative and positive on contact. The accumulation must be referred to *induction*, which takes place in the electrical column (129) through the very thin stratum of air or paper, and through water when that fluid is interposed between the plates. Accordingly we observe that the apparatus is in the condition of the series of conductors with interposed air (112) and of the Leyden phials (118). When the electric column is insulated the extremities exhibit feeble negative and positive powers, but if either extremity be connected with the ground, the electricity of its poles or extremities is greatly increased, as may be shown by the increased divergence of the leaves of the electrometer which then ensues.

Electricity continually active in nature. 146. As general changes in the form and constitution of matter are connected with its electrical states, it is obvious that electricity must be continually active in nature. Its effects are exhibited on a magnificent scale in the thunder-storm, which results from the accumulation of electricity in the clouds, as was first experimentally demonstrated by Dr. Franklin, who also first showed the advantage of pointed conductors as safeguards to buildings. Lightning rods. In these cases the conducting rod or rods should be of copper or iron, and from half to three-fourths of an inch diameter. Its upper end should be elevated three or four feet above the highest part of the building, and all the metallic parts of the roof should be connected with the rod, which should be perfectly continuous throughout, and passing down the side of the building, penetrate several feet below its foundation, so as always to be immersed in a moist stratum of soil, or if possible, into water. The leaden water-pipes attached to houses often might be made to answer the purpose of conductors, especially when thick enough to resist fusion.

During a thunder-storm the safest situation is in the middle of a room, at a distance from the chimney, and standing upon a woollen rug, which is a nonconductor. Blankets and feathers being nonconductors, bed is a place of comparative safety, provided the bell-wires are not too near, which are almost always melted in houses struck by lightning. When out of doors, it is dangerous to take shelter under trees: the safest situation is within some yards of them, and upon the dryest spot that can be selected.

Discharge of lightning. The discharge of electricity in a thunder-storm is sometimes only from cloud to cloud; sometimes from the earth to the clouds; and sometimes from the clouds to the earth, as one or other may be positive or negative. When aqueous vapour is condensed, the clouds formed are usually more or less electrical; and the earth below them being brought into an opposite state, by induction, a discharge takes place when the clouds approach within a certain distance, constituting lightning; and the undulation of the air, produced by the discharge, is the cause of thunder, which is more or less intense, and of longer or shorter duration, according to the quantity of air acted upon, and the distance of the place, where the report is heard from the point of the discharge. It may not be uninteresting to give a further illustration of this idea; electrical effects take place in no sensible time; it has been found that a discharge through a circuit of four miles is instantaneous; but sound moves at the rate of about twelve miles in a minute. Now, supposing the lightning to pass through a space of some miles, the explosion will be first heard from the point of the air agitated, nearest to the spectator; it will gradually come from the more distant parts of the course of the electricity, and last of all, will be heard from the remote extremity; and the different degrees of the agitation of the air, and likewise the difference of the distance, will account for the different intensities of the sound, and its apparent reverberations and changes.

Mode of determining its distance.

"In a violent thunder-storm, when the sound instantly succeeds the flash, the persons who witness the circumstance are in some danger; when the interval is a quarter of a minute, they are secure."—Davy's *Elements*, p. 139.

Apparatus to shew the operation of lightning conductors.

147. A variety of electrical apparatus has been devised to illustrate the operation of conductors for lightning, and the advantage of points over balls; the simplest consists of a model of a house having a conductor with a break in it, in which some inflammable matter should be placed; the lower end of the conductor should be communicated with the exterior of a charged Leyden phial, the knob of which, brought over its upper end, will then represent a thunder-cloud. If the conductor be pointed, it will be slowly discharged; if surmounted by a ball, there will be an explosion, and the combustibles probably inflamed.

Aurora borealis & water spout.

148. The coruscations of the *aurora borealis* are also probably electrical, and much resemble flashes of electric light traversing rarefied air. The *water-spout* may be referred to the same source, and is probably the result of the operation of a weakly electrical cloud, at an inconsiderable elevation above the sea, brought into an opposite electrical state: and the attraction of the lower part of the cloud, for the surface of the water, may be the immediate cause of this extraordinary phænomenon.

Electrical fishes.

149. In the *gymnotus* or *electric eel*, and in the *torpedo* or *electric ray*, are arrangements, given to those remarkable animals for the purposes of defence, which certain forms of the Voltaic apparatus much resemble, for they consist of many alternations of different substances. These electrical organs are much more abundantly supplied with nerves than any other part of the animal, and the two frequent use of them is succeeded by debility and death.—Todd, *Phil. Trans.*, 1817.

Arrangements of organic substances admit of producing electrical effects.

That arrangements of different organic substances are capable of producing electrical effects, has been shown by various experimentalists. If the hind legs of a frog be placed upon a glass plate, and the crural nerve dissected out of one made to communicate with the other, it will be found, upon making occasional contacts with the remaining crural nerve, that the limbs of the animal will be agitated at each contact. These circumstances have induced some physiologists to suppose that electricity may be concerned in some of the most recondite phænomena of vitality, and Dr. Wollaston, Sir E. Home, and myself, have made some experiments tending to confer probability on this idea.—*Phil. Trans.*, 1809.

Electricity concerned in the phænomena of vitality.

Theories.

150. We have as yet no plausible hypothesis concerning the *cause* of electrical phænomena, though the subject has engaged the attention of the most eminent philosophers of Europe. They have been by some referred to the presence of a peculiar fluid existing in all matter, and exhibiting itself by the appearances which have been described, whenever its equilibrium is disturbed, presenting negative and positive electricity when deficient and when redundant. Others have plausibly argued for the presence of two fluids, distinct from each other. Others have considered the effects as referable to peculiar exertions of the attractive powers of matter, and have regarded the existence of any distinct fluid or form of matter to be as unnecessary to the explanation of the phænomena, as it is in the question concerning the cause of gravitation.

Experiments seeming to favour one more than another.

151. When the flame of a candle is placed between a positive and negative surface, it is urged towards the latter; a circumstance which has been explained upon the supposition of a current of electrical matter passing from the positive to the negative pole; indeed, it has been considered as demonstrating the existence of such a current of matter. But if the flame of phosphorus be substituted for that of a candle, it takes an opposite direction; and, instead of being attracted towards the negative, it bends to the positive surface. It has been shown that inflammable bodies are always attracted by negative surfaces, and acid bodies, and those in which the supporters of combustion prevail, are attracted by positive surfaces (137.) Hence the flame of the candle throwing off carbon, is directed to the negative pole, while that of phosphorus forming acid matter goes to the positive, consistently with the ordinary laws of electrochemical attraction.—*Phil. Trans.*, 1814.

Experiments in opposition to electricity being material.

152. There are other experiments opposed to the idea that electricity is a material substance. If we discharge a Leyden phial through a quire of paper, the perforation is equally burred upon both sides, and not upon the negative side only, as would have been the case if any material body had gone through in that direction. The power seems to have come from the centre of the paper, as if one half of the quire had been attracted by the positive, and the other by the negative surface.

One of a contrary tendency.

153. When a pointed metallic wire is presented towards the conductor of the electrical machine, in a darkened room, a star of light is observed when the conductor is positive, but a brush of light when it is negative; a circumstance which has been referred to the reception of the electric fluid in the one case, and its escape in the other. In the Voltaic discharge the same appearances are evident upon the charcoal point, rays appearing to diverge from the negative conductor, while upon the positive a spot of bright light is perceptible. But these affections of light can scarcely be considered as indicating the emission or reception of any specific form of matter.

CHAPTER II.

OF RADIANT OR IMPONDERABLE MATTER.

Too subtile for the usual modes of examination.

154. Of the substances belonging to our globe, some are of so subtile a nature as to require minute and delicate investigation to demonstrate their existence; they can neither be confined, nor submitted to the usual modes of examination, and are known only in their states of motion as acting upon our senses, or as producing changes in the more gross forms of matter. They have been included under the general term of RADIANT OR IMPONDERABLE ETHEREAL MATTER, which as, it produces different phænomena, must be considered as differing either in its nature or affections. Respecting the nature of these phænomena, two opinions have been entertained, and each ably supported. It has been supposed by Huygens and Descartes, that they arise from vibrations of a rare elastic medium which fills space; while Newton has considered them as resulting from emanations of particles of matter.

Leading Theories of Descartes and Newton.

The other forms of matter are tangible and ponderable, and, therefore, easily susceptible of accurate examination; they may be considered as resulting from the mutual agencies of heat and attraction, and are comprehended under the three classes of *Solids*, *Liquids*, and *Gases*.

SECTION I. *Of the Effects of Radiant Matter in producing the Phænomena of Vision.*

155. THE minute investigation of those laws of light which relate to its motion, and effects in producing vision, constitutes a branch of the science of Optics, and therefore belongs to Mechanical Philosophy; it is, however, requisite that some of them should partially be considered as bearing upon important questions of chemical inquiry.

Vision.

The phænomena of vision are produced either by bodies inherently luminous, such as the sun, the fixed stars, and incandescent substances; or they are referable to the reflection of light from the surfaces of bodies. It is thus that the objects around us are visible by reflecting the sun's rays, in the day-time, but become lost in obscurity when that luminary sinks beneath the horizon.

Light transmitted in right lines.

156. The manner in which the eye is affected by luminous bodies shows that light is transmitted in right lines, and every right line drawn from a luminous body to the eye is termed a *ray of light*, and as a congeries of rays possesses the same properties as the single ray, the same abstract term is frequently employed to designate the congeries.

Rate of lights motion.

157. The discoveries of Roemer, (*Phil. Trans.*, Vol. xii.) and of Bradley, (*Phil. Trans.*, Vol. xxxv. and xlv.) have shown that light is about eight minutes and thirteen seconds in passing from the sun to the earth, so that it may be considered as moving at the rate of 200,000 miles in a second.

Newton's idea of opacity & transparency.

158. Some bodies intercept light or are *opaque*: others allow its transmission, or are *transparent;* and there are gradations from perfect opacity to nearly perfect transparency. It is probable that opacity results from the attraction of the substance for light, and not from its density, for it can scarcely be supposed that the particles of bodies should not be far enough distant to allow of the passage of light. Newton supposes the particles of transparent bodies to be of uniform density and arrangement, and attracting the ray of light equally in every direction, they suffer it to pass through them without obstruction; whereas, in opaque bodies, the particles are either of unequal density or irregularly arranged, and the light being unequally attracted, cannot therefore penetrate the body.

Effect of different densities in the media.

159. When a ray of light passes through the same medium, or when it passes perpendicularly from one transparent medium into another, it continues to move without changing its direction; but, when it passes obliquely from one medium into another of a different density, it is thrown more or less out of its old direction, and is said to be *refracted.* The refraction is *towards* the perpendicular when the ray passes into a denser medium, and *from* the perpendicular when it passes into a rarer medium. The medium in which the rays of light are caused to approach nearest to the line perpendicular to its surface, is said to have the greatest refractive density.

Refractive Power depends on the chemical nature as well as density.

Refractive power of compounds not the mean of that possessed by their constituents.

160. The density of bodies is by no means the only circumstance that effects their refractive power, it also depends upon their chemical nature; and generally speaking those substances have the greatest refractive power which are combustible, or which contain an inflammable basis: the refractive power of compounds is not the mean deduced from that of their components; which, however, it generally is in mere mixtures. The following table exhibits the refractive powers of several gaseous and solid bodies, from the experiments of Biot and Arago, and from NEWTON's *Optics:*

Table of the refractive powers of some bodies.

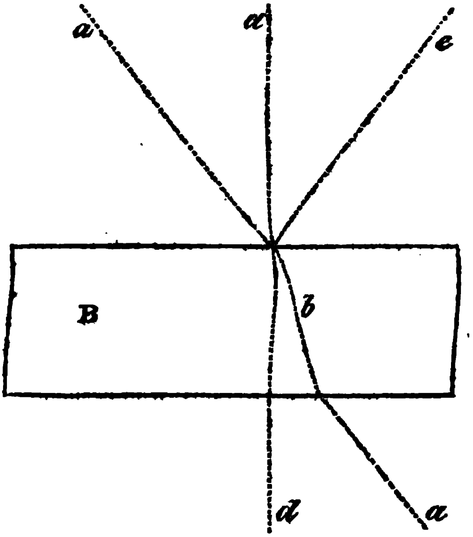
Atmospheric air	1.00000
Oxygen	0.86161
Nitrogen	1.03408
Hydrogen	6.61436
Ammonia	2.16851
Carbonic acid	1.00476
Carburetted hydrogen	2.09270
Muriatic acid gas	1.19625
Muriatic ether, in gaseous state	1.71344
Water	1.7225
Alcohol	2.2223
Olive oil	2.7684
Diamond	3.1961
Gum Arabic	1.8826

Reflected light.

161. When the rays of light arrive at the surfaces of bodies, a part of them, and sometimes nearly the whole, is thrown back, or *reflected,*

and the more obliquely the light falls upon the surface, the greater in general is the reflected portion. In these cases the angle of reflection is always equal to the angle of incidence.

Let *a a* represent pencils of light falling upon the surface of a polished piece of glass B, the perpendicular pencil will pass on in a straight line to *d*. Of the oblique pencil, one portion will enter the glass and suffer refraction towards the perpendicular as at *b*, and re-entering the atmosphere, it will bend from the perpendicular, and re-assume its former direction, as at *c*. Another portion of the oblique pencil will be reflected at an angle equal to that of its incidence, as at *e*.



162. When a ray of light passes through an oblique angular crystalline body, it exhibits peculiar phænomena; one portion is refracted in the ordinary way; another suffers extraordinary refraction, in a plane parallel to the diagonal joining the two obtuse angles of the crystal; so that objects seen through the crystal appear double. Transparent rhomboids of carbonate of lime, or Iceland crystal, exhibit this phænomenon of *double refraction* particularly distinct.

Double refraction.

If a ray of light, which has thus suffered double refraction, be received by another crystal, placed parallel to the first, there will be no new division of the rays; but if it be placed in a transverse direction, that part of the ray which before suffered ordinary refraction will now undergo extraordinary refraction, and reciprocally that which underwent extraordinary refraction now suffers ordinary refraction.

Ordinary & extraordinary refraction.

If the second crystal be turned gradually round in the same plane, when it has made a quarter of a revolution there will be four divisions of the ray, and they will be reduced to two in the half of the revolution; so that the refracting power appears to depend upon some relation of the position of the crystalline particles.

Refracting power seems dependant upon some position of crystalline particles.

163. When light is reflected from bodies, it retains, under many circumstances, its former relations to the refractive power of transparent

media; but, in certain cases, at angles differing for different substances, the reflected rays exhibit peculiar properties, analogous to those which have suffered extraordinary refraction. Thus, if the flame of a taper reflected at an angle of 52° 45′ from the surface of water, be viewed through a piece of doubly refracting spar, one of the images will vanish every time that the crystal makes a quarter of a revolution.

Angle of incidence eqaul to the angle of reflection.

Curious instance of the transmission and reflection of light.

Polarisation of light.

164. When a ray of light is made to fall upon a polished glass surface, at an angle of incidence of 35° 25′, the angle of reflection will be equal to that of incidence. Let us suppose another plate of glass so placed that the reflected ray will fall upon it at the same angle of 35° 25′; this second plate may be turned round its axis without varying the angle which it makes with the ray that falls upon it. A very curious circumstance is observed as this second glass is turned round. Suppose the two planes of reflection to be parallel to each other, in that case the ray of light is reflected from the second glass in the same manner as from the first. Let the second glass be now turned round a quadrant of a circle, so as to make the reflecting planes perpendicular to each other: now, the whole of the ray will pass through the second glass, and none of it will be reflected. Turn the second glass round another quadrant of a circle, so as to make the reflecting planes again parallel, and the ray will again be reflected. When the second glass is turned round, three quadrants, the light will be again transmitted, and none of it reflected. Thus, when the reflecting planes are parallel, the light is reflected, but when they are perpendicular the light is transmitted. This experiment proves, that, under certain circumstances, light can penetrate through glass when in one position, but not in another. This curious fact was first observed by Malus, who accounted for it by supposing the particles of light to have assumed a particular position as a needle does when under the influence of a magnet, and hence he called this property of light, its *Polarisation*. (THOMSON's *System*, Vol. i. p. 16.) It has since been studied with laborious diligence by Dr. Brewster, and by M. M. Arago and Biot,—*Phil. Trans.* 1813, 1814, 1815, 1816, 1817.—*Annales de Chimie*, tom. 94.—*Traité de Physique.*

165. If plates of mica, and certain other crystallized substances, be placed between the glasses employed in the above experiments, so that the reflected rays may traverse them in passing from one surface to the other, it will be found that under certain circumstances, the image of the candle will remain visible; in other words, the light will be *depolarised* in passing through the crystallized medium. Common glass is generally incapable of depolarising the ray, but it acquires the depolarising power when submitted to pressure, or heated, or when it has been heated and very suddenly cooled; the influence of its particles upon those of light becoming then analogous to crystallized bodies.

Prismatic colours.

166. That a sunbeam, in passing through a dense medium, and especially through a triangular prism of glass, gives rise to a series of brilliant tints similar to those of the rainbow, was known in the earliest ages, but it required the sagacity of Newton to develope the cause of the phænomenon. He proved, that light consists of rays differing from each other in their relative refrangibilities; and, guided by their colour considered their number as seven: red, orange, yellow, green, blue, indigo, and violet. If the prismatic colours, or *spectrum*, be divided into 360 equal parts, the red rays will occupy 45 of these parts, the orange 27, the yellow 48, the green 60, the blue 60, the indigo 40, and the

violet 80. Of these rays the red being least refrangible, fall nearest that spot which they would have passed to, had they not been refracted; while the violet rays being most refrangible, are thrown to the greatest distance; the intermediate rays, possess mean degrees of refrangibility.

Newton's theory of colours

167. These differently-coloured rays are not susceptible of further decomposition, by any number of refractions, but when they are collected into a focus they re-produce white light. Upon these phænomena is founded the Newtonian *theory of colours*, which supposes them to depend upon the absorption of all rays, excepting those of the colour observed. Thus green bodies reflect the green rays and absorb the others. All the rays are reflected by white bodies, and absorbed by those which are black.

SECTION II. *Of the Operation of Radiant Matter in producing Heat.*

Relative temperature of the prismatic rays.

Calorific, and colorific rays separated by the prism.

168. IF a solar beam be refracted by a prism, and the coloured image received upon a sheet of paper it will be found, on moving the hand gently through it, that there is an evident increase of temperature towards the red ray. This fact seems to have been first noticed by Dr. Hutton (*Dissertation on Light and Heat*, p. 39;) but it is to Dr. Herschel (*Phil. Trans.* 1800,) that we are indebted for a full investigation of the subject. If the coloured rays be thrown successively upon delicate thermometers, it will be found, that if the heating power of the violet rays be considered = 16, that of the green rays will be = 26, and of the red = 55. These circumstances suggested the possibility of the heating power of the spectrum extending beyond the red ray; and on applying a thermometer just out of the red ray, and beyond the limits of the visible spectrum, this was found to be the case. A thermometer in the red ray rose 7° in ten minutes, but just beyond the red ray the rise was =9°. It is evident, therefore, that, independent of the illuminating rays, there are others which produce increase of temperature, and these from their increase towards the red ray, and from the spot which they principally occupy in the refracted congeries, are possessed of less refrangibility than the visible rays.

Maximum of temperature at the extremity of the red ray.

Dr. Herschel's experiments were repeated, with nearly similar results, by Sir H. Englefield, in 1802, and by Mr. Berard, in 1813 (THOMSON'S *Annals*, ii, 163,) who found the maximum of heat to exist just at the extremity of the red ray.

Concentration of these temperatures.

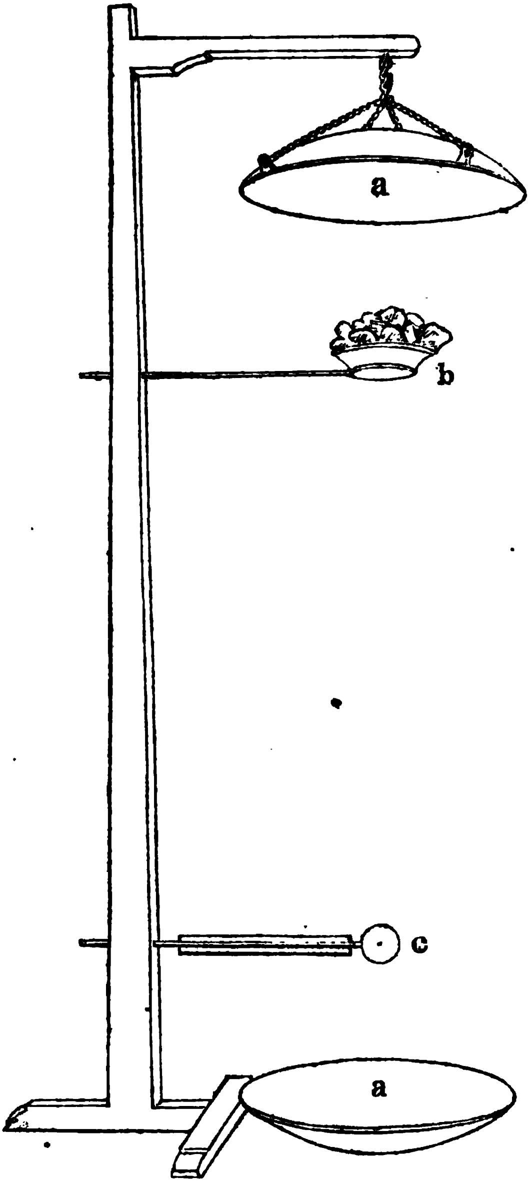
169. That these calorific rays are susceptible of refraction and reflection, is proved by the intense heat produced when the solar rays are concentrated into a focus by a lens, or by a concave mirror.

Terrestial and solar radiant matter have each some peculiarities differing from the other.

170. The radiant matter, emitted by terrestial bodies at high temperatures, agrees in many of its properties with that constituting the solar rays, but in others it presents apparent peculiarities: the investigation of this subject constitutes a beautiful department of philosophic inquiry.

Reflected caloric.

The effect we perceive in approaching a fire chiefly results from radiation and is little connected with the immediate conducting power of the air; and if a concave *metallic* mirror be held opposite the fire a heating and luminous focus will be obtained. The affections of terrestrial radiant matter are best demonstrated by employing two concave mirrors of planished tin or plated copper, placed at a distance of about ten feet asunder. (Pictet, *Essais de Physique.*) Under these circumstances when a thermometer is in the focus of one of the mirrors, it will be found sensible to the effects of a heated body placed in the focus of the opposed mirror; and that the effect is produced by reflection, and not by mere direct radiation, is proved, either by drawing the thermometer out of the focus towards the opposed mirror, or by placing a screen between the thermometer and its mirror, when diminution of temperature is in either case



Pictet's experiment.

indicated. In these experiments the differential thermometer (66) is most advantageously employed, and the mirrors may be placed opposite each other on the ground, or vertically suspended as in the woodcut, where *a a* represent the mirrors, *b* a pan of hot charcoal, *c* an air thermometer.

Separation of light from caloric.

171. If the flame of a candle be placed in the focus of one mirror, a heating and luminous focus is obtained from the other: but if a plate of glass be now interposed between the two mirrors, the rays of heat are arrested, while those of light, freely passing through the glass, are collected, as usual in the opposite focus. It has hence been concluded that there is a difference between solar and terrestrial heat; the rays of the former passing through glass without heating it; while the rays of the latter are stopped by glass, and it becomes hot when opposed to them. —(SCHEELE's *Experiments on Air and Fire.*) But the rays of burning bodies may in many instances be shown to pass through glass with great facility; thus a bright gas flame affords a heating as well as a luminous focus, when its rays are concentrated by a double convex lens, upon the bulb of an air thermometer.—BRANDE, *Phil. Trans.* 1820. p. 27.

172. In these experiments upon the radiation of terrestrial heat, the temperature excited by the radiant matter appears always relative to that of the heated or radiating body; and if we assume that all bodies are constantly throwing off radiant matter, the effects of temperature which it produces when condensed or collected into a focus by a concave mirror, will bear a relation to the source; for the particles may be conceived to move with such velocity as not to be affected by circumjacent bodies, or by the circumambient air. Thus, white-hot iron produces a greater effect upon the focal thermometer than that which is only red-hot, and red-hot iron causes a greater effect than hot water; a body of the same temperature as the thermometer causes no change in it; but cold bodies produce an effect of cold, because the particles which they radiate, when stopped by impinging upon the thermometer-bulb, are of a lower temperature.

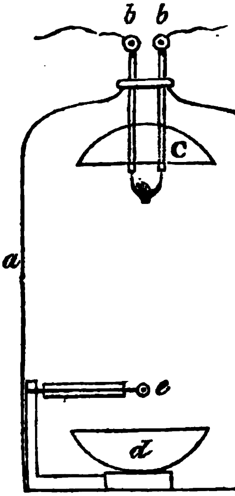
Radiation considered as depending upon the undulations of air.

173. Radiation has by some been accounted for upon the idea of the heated body producing undulations in the air, something analogous to the waves excited by sonorous bodies; but the different phænomena of prismatic refraction and of solar and terrestrial radiation are not satisfactorily explained upon such an hypothesis.

Newton's idea of refrangibility.

Newton endeavoured to explain the different refrangibility of the rays of light, by supposing them composed of particles of different sizes; and adopting this hypothesis, we should say, that the particles of red light were largest, those of violet light smallest. The heating rays (168) would consist of particles yet larger than those producing colour; and the smallest particles, or most attenuated radiant matter, would be that which produces certain chemical changes (180.)—(NEWTON's *Optics.*) Upon this hypothesis, too, it would appear that the particles of terrestrial heat are of so large a size as to be partially arrested in their progress by glass and other transparent bodies which allow a free passage to solar radiant matter.

Newton has also put the query, "whether light and common matter are not convertible into each other?" And if we consider sensible heat in bodies to depend upon vibrations of their particles, a certain intensity of vibrations may send off particles into free space; and particles moving rapidly in right lines, may, in losing their own motion, communicate a vibratory motion to the particles of terrestrial bodies.—DAVY's *Elements*, p. 215.



Radiation in elastic media and the Torricellian vacuum.

174. Radiation goes on in all elastic media, and in the Torricellian and air-pump vacuum, as may be shown by igniting charcoal by means of the Voltaic battery, placed in the focus of a small mirror confined in the exhausted receiver of the air-pump. Sir. H. Davy found that the receiver being exhausted to $\frac{1}{120}$, the effect upon the thermometer in the opposite focus was nearly three times as great as when the air was in its natural state of condensation, *a* is the receiver, *b b* the insulated wires connected with the voltaic apparatus igniting the charcoal in the focus of the upper mirror c. In the focus of the lower mirror *d* is the thermometer *e*.

Heating effect of solar rays with regard to superficial colours.

175. It has long been known, in regard to solar rays, that their heating effect depends much upon the colour of the surfaces upon which they impinge, and that black and dark bodies are more heated than those which are white or of light tints, circumstances dependent upon absorption and reflection.

Radiation of caloric in direct proportion to its degree of absorption.

Professor Leslie has shown that the phænomena of terrestrial radiation are connected with the nature of the radiating surface; and that those surfaces which are the best radiators of this heat are also gifted with the greatest absorbing power.—Leslie *on Heat.*

Unmetallic and unpolished surfaces are the best radiators, and also the best receivers of radiant heat; while polished metallic substances are the worst radiators, and have the lowest absorbing powers. In the experiments with the metallic mirrors, the whole nearly of the heat is reflected, and the mirror itself does not become warm: but if it be coated with any unpolished, and especially unmetallic coating, as with paper, or paint, the reflection is then scarcely perceptible and the mirror becomes hot from the absorption of the radiant matter.

In Professor Leslie's experiments it was found, that a clean metallic surface produced an effect = 12 upon the thermometer. When covered with a thin coat of glue, its radiating power was so far increased as to produce an effect = 80; and, on covering it with lamp-black, it became = 100.

Radiation independent of superficial colour.

In these cases of radiation, the *colour* of the surface does not interfere, and the different effects must be referred to the mechanical structure of the radiating surface. White paper and lamp-black produce nearly the same effects; and paper, coloured blue, red, yellow, and green, does not differ in radiating power from that which is white, provided the colour produces no change of texture in the paper.

176. The connexion of the receptive with the radiating power is made obvious by coating the bulbs of thermometers with different substances. Thus, the effect of radiant heat upon a thermometer bulb covered with a thin coating of lamp-black being = 100; when the bulb is covered with silver-leaf the effect is only = 12. M. M. Dulong and Petit, in their valuable *Memoir on Heat*, which gained the

prize-medal of the Academy of Sciences for 1818, have detailed a variety of important facts upon the subject of the radiation of surfaces.

Photometer of Leslie.

177. Upon the principle of the absorption of the solar rays by blackened surfaces, Mr. Leslie has constructed a *photometer*. It is merely a very delicate and small differential thermometer, enclosed in a thin and pellucid glass tube. One of the bulbs is of black glass, which when the instrument is suddenly exposed to light, becoming warmer than the clear bulb, indicates the effect by the depression of the fluid. (Leslie *on Heat*, p. 424.) A differential thermometer containing the vapour of ether, may also, in certain experiments, be advantageously used as a *Photometric Thermometer*.—Brande, *Phil. Trans.* 1820.

Vessels intended to retain caloric should be clean and metallic.

178. It is obvious, from the above-mentioned facts, that all vessels intended to retain heat, should be clean and metallic, for polished metallic surfaces have very low radiating powers; whereas those vessels which are either to receive, or to radiate, should be blackened upon their surfaces. The knowledge of these properties is economically applicable in a variety of cases.

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Section III. *Of the Influence of Radiant Matter in producing Chemical Changes.*

Radiant matter possesses considerable influence over the chemical energies of bodies.

179. Radiant matter possesses considerable influence over the chemical energies of bodies. If a mixture of equal volumes of the gases called chlorine and hydrogen be exposed in a dark room, they slowly combine, and produce muriatic acid gas; but, if exposed to the direct rays of the sun, the combination is very rapid, and often accompanied by an explosion.

Chlorine and carbonic oxide have scarcely any tendency to combine, even at high temperatures, when light is excluded, but exposed to the solar rays they enter into chemical union. Chlorine has little action upon water, unless exposed to light; and, in that case, the water, which consists of oxygen and hydrogen, is decomposed. The hydrogen unites with the chlorine to produce muriatic acid, and the oxygen is evolved in a gaseous form.

Produces chemical changes.

180. These, and numerous other similar cases which might be adduced, show that radiant matter influences the chemical energies of bodies, independent of its heating powers. Scheele (*Experiments on Air and Fire*, p. 78, *&c.*) was the first who entered upon this curious investigation; and many important facts connected with it have been more lately ascertained by Ritter, Wollaston, and Davy. Scheele threw the prismatic spectrum upon a sheet of paper, moistened with a solution of nitrate of silver, a salt quickly decomposed by the agency of light. In the blue and violet rays the silver was soon reduced, producing a blackness upon the paper, but in the red ray scarcely any similar effect was observed. Wollaston and Ritter discovered that these chemical changes were most rapidly effected in the space which bounds the voilet ray, and which is out of the visible spectrum.

Division of solar rays by refraction.

181. It has been thus ascertained, that the solar beams are refrangible into three distinct kinds of rays; the *calorific*, or heating rays; the *luminous*, or *colorific*, rays, which produce vision and colour; the *decomposing* rays, or those which have a tendency to interfere with the chemical constitution of bodies.

Not perfectly exhibited in the prismatic spectrum.

In the prismatic spectrum these three sets of rays are imperfectly separated, and arranged according to their respective refrangibilities. The heating rays are the least refrangible, the colorific rays are possessed of more refrangibility, and the decomposing, or, as some have called them, the *deoxidizing rays*, are the most refrangible.

Analogy between the effect of the solar ray and that of electricity.

182. Sir H. Davy has observed, that certain metallic oxides, when exposed to the violet extremity of the prismatic spectrum, undergo a change similar to that which would have been produced by exposure to a current of hydrogen; and that, when exposed to the red rays they acquire a tendency to absorb oxygen. (*Elements of Chemical Philosophy.*) In such general facts, he traces an analogy between the effects of the solar beam, and the agencies of electricity. In the Voltaic circuit, the maximum of heat is at the positive pole, where the power of combining with oxygen is also given to bodies; the agency of rendering bodies inflammable is exerted at the opposite surface; and similar chemical effects are produced by negative electricity, and by the most refrangible rays; and by positive electricity, and the rays which are least refrangible.

The violet ray of the spectrum capable of exciting magnetic polarity.

183. It has been asserted by Morichini, and the experiment is said to have succeeded in other hands, that the prismatic spectrum is capable of exciting the magnetic influence, and that a needle exposed to the violet rays acquires polarity: this would point out a further analogy between the agencies of light and electricity. (136.)

Perfect vegetation requires the influence of solar rays.

184. In nature the influence of the solar rays is very complex, and the growth, colour, flavour, and even the forms of many vegetables, are much dependent upon them. This is seen in many plants which are protected from the sun's rays: celery and endive are thus cultivated with the view of rendering them palatable; and plants which are made to grow in a room imperfectly illuminated, always bend towards the apertures by which the sun's rays enter. The changes too which vegetables effect upon the circumambient atmosphere are influenced by the same cause.

In the animal creation, brilliancy of colour and gaudy plumage belong to the tropical climates; more sombrous tints distinguish the polar inhabitants; and dull colours characterize nocturnal animals, and those who chiefly abide below the surface.

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SECTION IV. *Of the Phænomena exhibited by Luminous and Incandescent Bodies, and of the Nature and Properties of Flame.*

Phosphorescent bodies.

185. THERE are many substances which, when heated to a certain point, become luminous without undergoing combustion, and such bodies are said to be *phosphorescent*. The temperatures which they require for this purpose are various; it generally commences at about

400°, and may be said to terminate at the lowest visible redness. Some varieties of phosphate of lime, of fluor spar, of bituminous carbonate of lime, of marble, and sand, and certain salts, are the most remarkable bodies of this description. (Wedgwood, *Phil. Trans.* Vol. 82.) Their luminous property may be best exhibited by scattering them in coarse powder upon an iron plate heated nearly to redness. Oil, wax, spermaceti, and butter, when nearly boiling, are also luminous.

Solar phosphori.

Canton's compound.

186. Another class of phosphorescent bodies have been termed *solar phosphori*, from becoming luminous when removed into a dark room after having been exposed to the sunshine. Of this description are Canton's, Baldwin's, and the Bolognian phosphorus. Canton's phosphorus is prepared thus:—Calcine oyster-shells in the open fire for half an hour, then select the whitest and largest pieces and mix them with one third their weight of flowers of sulphur, pack the mixture closely into a covered crucible, and heat it to redness for an hour, When the whole has cooled, select the whitest pieces for use.—*Phil. Trans.* Vol. 58.

Baldwin's and the Bolognian phosphorus.

Baldwin's phosphorus is prepared by heating nitrate of lime to a dull red heat, so as to form it into a compact mass: and the Bolognian phosphorus, discovered by Vincenzio Cascariolo, a shoemaker of Bologna, is made by reducing compact sulphate of baryta to a fine powder, which is formed into cakes with mucilage, and these are heated to redness.—Aikin's *Dictionary*, Art. *Phosphori*.

Wilson's experiments.

Mr. B. Wilson has also made a variety of curious experiments on solar phosphori; and, he has discovered the simplest and most effectual of these bodies, which may be obtained by closely observing the following directions:—Take the most flaming coals off a brisk fire, and throw in some thick oyster-shells; then replace the coals, and calcine them for an hour; remove them carefully, and, when cold, it will be found that after exposing them for a few minutes to the light, they will glow in the dark with most of the prismatic colours.—Wilson *on Phosphori*, p. 20.

Spontaneous Phosphori.

187. A third set of bodies, belonging to this class, are those which are *spontaneously phosphorescent*. Such are especially, the flesh of salt-water fish just before it putrefies, and decayed wood. The *glow-worm*, and the *lantern-fly*, are also luminous when alive; and the *hundred legged worm*, and some others, shine brilliantly when irritated.

It appears from the experiments of Canton and of Dr. Hulme, (*Phil. Trans.* Vols. lix. xc. and xci.) that sea-fish become luminous in about twelve hours after death, that it increases till putrefaction is evident, and that it then decreases. Immersion in sea-water does not affect this luminous matter, on the contrary, the brine is itself rendered luminous; but it is extinguished by pure water, and by a variety of substances which act chemically upon the animal matter.

Light from percussion or friction.

188. Percussion and friction are often attended by the evolution of light as when flint pebbles, pieces of sugar, and other substances, are struck or rubbed together.

Gases incapable of becoming luminous.

189. From experiments in which air has been intensely heated, it has been concluded that gaseous matter is incapable of becoming luminous; for, though the temperature of air be such as to render solid bodies white hot, it does not itself become visible. (Wedgwood, *Phil. Trans.* 1792.) Flame, however, may, in general, be regarded as luminous gaseous matter. Hydrogen gas, probably, furnishes the purest

form of flame which can be exhibited; for the flames of bodies which emit much light, derive that power from solid matter which is intensely ignited and diffused through them, and which, in ordinary flames, as of gas, tallow, wax, oil, *&c.*, consists of finely divided charcoal.

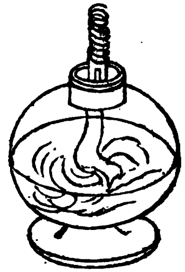
Hight and temperature of flame.

190. The intensity of the heat of flames which are but little luminous, as of hydrogen gas, spirit of wine, *&c.*, may be shown by introducing into them some fine platinum wire, which is instantly rendered white hot in those parts where the combustion is most perfect. It is even intensely ignited in the current of air above the flame, as may be shown by holding a piece of platinum-wire over the chimney of an Argand lamp fed with spirit of wine; the high temperature of this current is also exhibited by the common expedient of lighting paper by holding it in the heated air which rushes out of a common lamp-glass.

191. The high temperature of flame is further proved by certain cases of combustion without flame. Thus, if a heated wire of platinum be introduced into any inflammable or explosive mixture, it will become *ignited*, and continue so till the gas is consumed; but *inflammation* will, in most cases, only take place when the wire becomes white hot. This experiment is easily made by pouring a small quantity of ether into the bottom of a beer-glass, and holding, a piece of heated platinum wire a little above its surface; the wire becomes red hot, but does not inflame the vapour of the ether till it acquires an intense white heat.

Platinum wire lamp.

The same fact is exhibited by putting a small coil of platinum wire round the wick of a spirit lamp, which, when heated, becomes red hot, and continues so, as long as the vapour of the spirit is supplied, the heat never becoming sufficiently intense to produce its inflammation.



192. Such being the nature of flame, it is obvious, that if we *cool* it by any means, we must at the same time *extinguish* it. This may be effected by causing it to pass through fine wire gauze, which is an excellent conductor and radiator of heat, and consequently possessed of great cooling power. If a piece of fine brass or iron wire-gauze be brought down upon the flame of a candle, or what answers better, upon an inflamed jet of coal gas, it will, as it were, cut the flame in half. That the cooled gaseous matter passes through, may be shown by again lighting it upon the upper surface.

193. The power, therefore, of a metallic tissue thus to extinguish flame, will depend upon the heat required to produce the combustion, as compared with that acquired by the tissue; and the flame of the most inflammable substances, and of those that produce most heat in combustion, will pass through a metallic tissue that will interrupt the flame of less inflammable substances, or those that produce little heat in combustion; so that different flames will pass through at different degrees of temperature.

Davy's safety lamp.

194. The discovery of these facts, respecting the nature and properties of flame, led Sir H. Davy to apply them to the construction of the *Miners' safety lamp*, which will be explained under the article *Carburetted hydrogen gas.*

195. The phænomena exhibited by phosphorescent and incandescent bodies, and in the process of combustion, have sometimes been explained upon the idea that the light and heat evolved, were previously in combination with the substances, and that they are afterwards merely emitted, in consequence of decomposition; and that the solar phosphori absorb light and again give it out unchanged. But it appears more probable that any particles violently repelled into space may become radiant matter, than that it should consist of a *specific* substance: thus, mechanical action, and chemical changes, may each tend to the emission of radiant matter; and incandescence will result when the vibrations which heat occasions among the particles of bodies are of such violence as to cause their repulsion into space.

On the properties of phosphorescence and incandescence.

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CHAPTER III.

OF THE SIMPLE SUPPORTERS OF COMBUSTION.

196. THE substances belonging to this class are characterized by possessing very energetic powers of combination in respect to the simple inflammable bodies, and they are each of them capable of producing acids, whence they may also be termed *acidifying* principles. When their compounds are submitted to electro-chemical decomposition, these elements are attracted by the positive surface; hence their natural or inherent electrical states may be considered as negative.

Acidifying principles.

Electro negative.

These acidifying, electro-negative supporters of combustion, are three in number:

1. Oxygen.
2. Chlorine.
3. Iodine.

197. The following examples will serve to give some idea of the principles of nomenclature generally adopted in chemistry. The above bodies in entering into combination with each other, and with the bodies described in Chapters IV and V., produce two classes of compounds. Those which are not acid, are usually distinguished by the termination *ide*, as *oxide* of chlorine, *oxide* of nitrogen, *chloride* of sulphur, *iodide* of iron, *&c.*; and where more than one compound of this kind is produced, the terminations *ous* and *ic* are used to designate the relative proportions of the supporters of combustion. Thus nitrogen forms two oxides; that containing the smallest proportion of oxygen is

Chemical nomenclature.

the *nitrous* oxide, that containing the largest the *nitric* oxide. The acid compounds are similarly designated, as *nitrous* and *nitric* acid; *sulphurous* and *sulphuric* acid; and where there are intermediate compounds the term *hypo* is occasionally added to the acid next above it in point of oxidizement. Thus, *hyposulphuric acid* signifies an acid compound intermediate between the sulphurous and sulphuric acids; *hypophosphorous* acid, an acid containing less oxygen than the phosphorous acid.

The different combinations of the metals with oxygen, are perhaps best distinguished by prefixing to the word *oxide* the first syllable of the Greek ordinal numerals, as originally proposed by Dr. Thompson. Thus the *protoxide* of a metal will denote the compound containing a minimum of oxygen, or the first oxide which the metal is capable of forming; *deutoxide* will denote the second oxide of a metal, *&c.*; and when a metal is combined with the largest possible quantity of oxygen, the compound, if not acid, may be called *peroxide*. The same rule applies to the *chlorides* and *iodides*.

The acids terminating in *ous* produce compounds in which the termination *ite* is used; while those ending in *ic* form compounds in which the ending *ate* is used. Thus the combination of sulphurous acid and potassa, is a *sulphite* of potassa; that of sulphuric acid and potassa, a *sulphate* of potassa, *&c.*

When the same acid combines with more than one oxide of the same metal, the first syllable of the Greek ordinal numeral is in that case applied to the acid; thus, the *protosulphate* and *persulphate* of iron signify the combinations of sulphuric acid with the protoxide and peroxide of iron. The term *oxysulphate* is occasionally used to designate the latter compound, and in the same sense we speak of *oxynitrates*, *oxyphosphates*, *&c.*, but the former mode of designation is less equivocal.

The compounds of the simple inflammable bodies described in Chapter IV., with each other, and with those in Chapter V., are commonly designated by the termination *uret*, as *sulphuret* of phosphorus, *phosphuret* of carbon, *carburet* of iron, *&c.*

The terms *bi sulphuret*, *bi sulphate*, *bi phosphuret*, *bi phosphate*, *&c.*, applied to compounds, imply that they contain twice the quantity of sulphur, sulphuric acid, phosphorus or phosphoric acid, existing in the respective sulphuret, sulphate, phosphuret, and phosphate.

SECTION I. *Of Oxygen.*

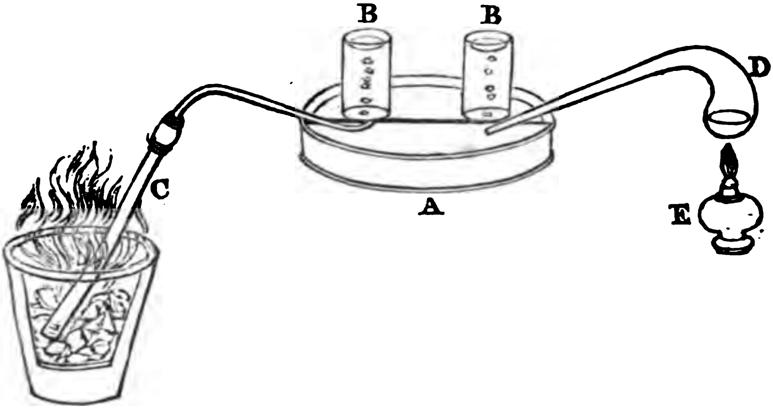
198. THIS elementary gaseous body may be obtained by heating to redness, in a glass retort, the salt called *chlorate of potassa* (546) 100 grains of which yield about 100 cubical inches; it may be collected over water in the hydro-pneumatic apparatus. It is also given off from black oxide of manganese, red oxide of lead, and nitre, when exposed to a red heat.

199. Common glass, or earthen-ware *retorts*, are used in these, and a variety of other chemical operations; or, where a red heat is re-

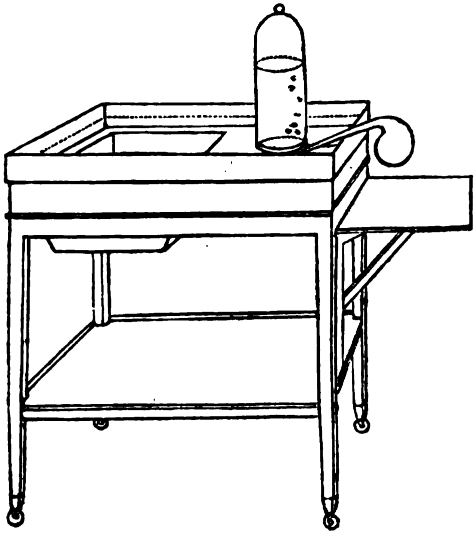
quired, they may be made of wrought iron, either in the same form, or in that of a bottle, tube, or other convenient shape.

200. The *hydro-pneumatic apparatus* consists of a japanned iron or copper vessel, of different shape and size according to the particular purposes for which it is intended, and containing a shelf perforated with holes through which the gas may pass into inverted vessels properly placed for its reception. In this wood-cut, A is the hydro-pneumatic trough; B B, inverted glasses for the reception of gas; C, a wrought iron tube placed in a pan of charcoal for the evolution of gases requiring a red heat; D, a retort heated by the spirit lamp E.

Hydro-pneumatic apparatus.

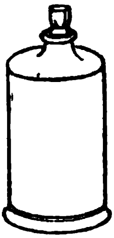


201. For experiments, in which larger vessels are employed for collecting or transferring gases, the annexed form of the apparatus is most convenient.



202. Vessels of various forms are employed for receiving, retaining, and measuring, gases. Where it is intended to introduce different substances into the gas, they may be of the form represented in figure 1, drawn into a neck with a glass-stopper at top, and open at bottom. Some of these should be graduated into cubic inches, and supplied with a stop-cock, as in figure 2. For measuring small quantities of gases, tubes are employed, some of which should be divided into 100 equal parts, others into tenths and hundredths of a cubical inch. Figures 3, 4.

1



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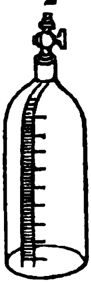

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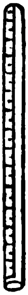

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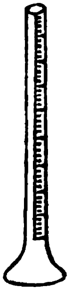
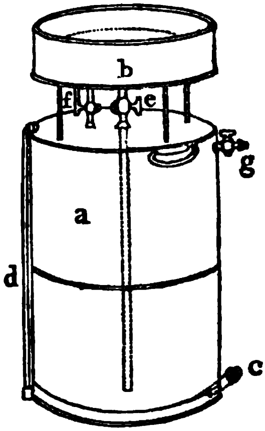


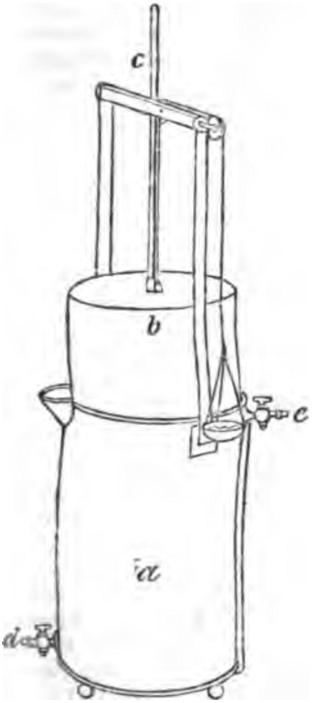
Gasholder of Mr. Pepys.

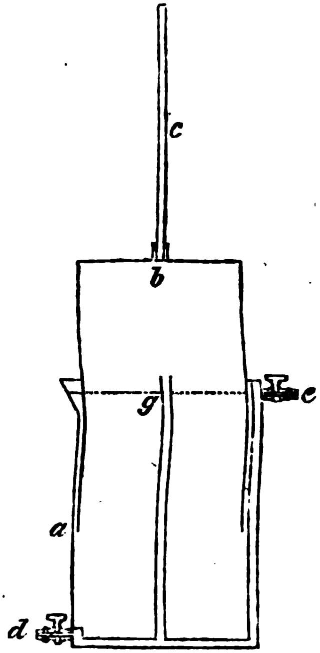
203. Where large quantities of gases are required to be collected and preserved, we employ *gasholders* and *gasometers*. The annexed cut represents Mr. Pepys's improved gasholder, made of japanned iron, or what is preferable, of copper. It consists of a body or reservoir *a*, which may hold from two to six or eight gallons. *b*, is a cistern from which issue two tubes, supplied with stop-cocks, one entering the reservoir at its upper part; the other continued as shown by the dotted lines to near the bottom. *c*, is a short tube issuing from the bottom of the reservoir, and capable of being accurately closed by a screw. *d*, is a glass tube communicating at both ends with the body of the gasholder. When it is intended to fill this apparatus with gas, the tube *c* is closed, and the stopcocks, *e f*, are opened; water is then poured into the cistern, which running down the long tube *e*, forces the air out through the shorter one *f*. The reservoir being thus filled, the stop-cocks are closed, and the aperture *c*, is opened, into which the beak of the retort, or tube, whence the gas issues, is introduced, and bubbling up, displaces the water which runs out at the same opening. When it is seen in the tube *d*, that nearly the whole of the water is displaced, the aperture is closed, and the vessel is now filled with gas, which may either be drawn off into receivers, placed in the cistern *b*, by opening the two stop-cocks *e f*; or



by closing the stop-cock *f*, and opening *g*, it may be propelled into bladders, or transferred in any convenient way by an attached tube.

A view and section of the *gasometer* are shown in the following sketches;





It may be made of japanned iron or copper. *a a*, is the outer circular vessel, or pail, to the sides of which the tubes, *d e*, (each fitted with a stop-cock externally) are soldered. The tube *d* penetrates at the bottom of the pail, and proceeds to the centre, where it joins the tube *e*, which enters the top of the pail and proceeds downwards; and from the place of junction, the upright tube *g* rises through the middle of the pail a little above the level of its upper rim. The vessel *b* is a cylinder open only at the bottom, and of less diameter than the pail into which it is inverted, and can move up and down freely. This cylinder has a solid stem *c*, which passes through a hole in the cross bar of the frame fixed to the top of the pail; it serves to steady the cylinder, and to indicate the quantity of the enclosed gas: the weight of the cylinder is counterpoised in any convenient way.

To use this gasometer, first let the cylinder fall to the bottom of the pail, and fill the latter with water; then shut the cock *e*, and open *d*, and connect with it the tube which conveys the gas from the retort or other vessel; or if more convenient, shut *d*, and convey the gas through *e*. The gas rises and gradually lifts up the cylinder, which must be properly balanced; and when sufficiently filled, the cock, by which it entered, must be closed. The gas may now be drawn off at either of the stop-cocks, by a tube passing into the water-trough, or it may be propelled through a blow-pipe, or otherwise employed.

Properties of oxygen gas.

204. *Oxygen gas is insipid, colourless, and inodorous; its specific gravity is 16 hydrogen being assumed = 1. 100 cubical inches at mean temperature and pressure weigh 33.88 grains.

Supports respiration.

205. It is a powerful supporter of respiration and combustion. A small animal, confined in oxygen gas, lives thrice as long as when confined in the same bulk of common air. A lighted taper, or a burning piece of sulphur, or phosphorus, introduced into this gas, is very rapidly consumed, with intense ignition.

Stahl's idea of combustion.

206. The phænomena of combustion were referred by Stahl and his associates, to a peculiar principle which they called *phlogiston;* it was supposed to exist in all combustibles, and combustion was said to depend upon its separation; but this explanation was absurdly at variance with the well-known fact, that bodies during combustion increase in weight.

Theory of Lavoisier.

Insufficient.

Combustion may be connected with the electrical energies of bodies.

After the discovery of oxygen gas, it was adopted by Lavoisier as the universal supporter of combustion. The basis of the gas was supposed to unite to the combustible, and the heat and light which it before contained in the gaseous state, were said to be evolved in the form of flame. But in this case, several requisites are not fulfilled; the light depends upon the combustible, and not upon the quantity of oxygen consumed; and there are very numerous instances of combustion in which oxygen, instead of being solidified, becomes gaseous during the operation; and, lastly, in others, no oxygen whatever is present. Combustion, therefore, cannot be regarded as dependent upon any peculiar principle or form of matter, but must be considered as a general result of intense chemical action. It may be connected with the electrical energies of bodies; for all bodies which powerfully act upon each other, are in the opposite electrical states of positive and negative; and the evolution of heat and light may depend upon the annihilation of these opposite states, which happens whenever they combine.

SECTION II. *Of Chlorine.*

207. To obtain this gas, a mixture of black oxide of manganese and muriatic acid may be heated over a lamp in a glass retort. It is

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* As the specific gravities and atoms of the simple gases seem to be equimultiples of each other and as Thomson for very fair reasons has assumed the atom of oxygen as unity as well as its specific gravity in his late excellent paper, (ann. Philos; October, 1820), we will follow him in order also to point out this interesting connexion. The specific gravity of oxygen will therefore be supposed = 1.0 it has also been established, that, the atoms of all bodies, as far as examination has gone, are individually equamultiplies of the atom of hydrogen—for the purpose therefore of commencing at a proper place, to exemplify this law, we shall here state the atom of hydrogen = 0.125 (that of oxygen being = 1), and refer to sect. 235 for the calculation.—

soon copiously evolved, and may be conveniently collected over warm water; it is absorbed by cold water, and cannot therefore be long retined over that fluid.

Method of obtaining chlorine.

It may also be procured from a mixture of 8 parts of common salt, 3 of black oxide of manganese, 4 of water, and 5 of sulphuric acid.

208. Chlorine was discovered by Scheele in 1774; it was called by him *dephlogisticated muriatic acid.* The term *oxymuriatic acid* was afterwards applied to it by the French chemists.

Time of discovery synonoms.

209. Chlorine is a permanently elastic gaseous fluid; it has a pungent and disagreeable smell, and is highly injurious when respired, even largely diluted with atmospheric air. Its colour is greenish yellow.

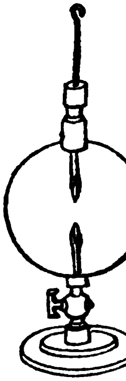
Characteristics.

210. When dry, it suffers no change by exposure to the most intense cold, but in its ordinary state it contains aqueous vapour, which, at a temperature of 32°, is deposited in the form of a white crystalline compound, which effervesces, and is again taken up by the gas, upon the application of heat.

211. Chlorine is not altered by exposure to very high temperatures. By means of the following apparatus, Sir H. Davy exposed it to the continued action of charcoal intensely ignited by Voltaic electricity, without the smallest change in its properties.

Unaltered in high temperatures.

A glass globe of about four inches' diameter, has at its upper part a sliding wire passing air-tight through a groundcollar, to the lower end of which is attached a piece of well-burned charcoal: at the bottom is a stop-cock supporting a brass pincers, in which is another pointed piece of charcoal; the globe is exhausted upon the air-pump, filled with chlorine, and the stop-cock and sliding wire attached to the extremities of the Voltaic apparatus; the charcoal points are then brought into contact by pushing down the upper wire, and they are thus retained as long as necessary in intense ignition.



*212. The specific gravity of chlorine, compared with hydrogen, is as 36 to 1; 100 cubic inches weigh 76.25 grains.

Specific gravity.

213. At the temperature of 60°, water dissolves two volumes of chlorine. The solution is of a pale yellow colour, has an astringent nauseous taste, and destroys vegetable colours: hence its use in bleaching; though the gas itself, when perfectly free from moisture, has scarcely any action upon them,

Solution in water, its use in bleaching.

214. When a burning taper is immersed in a jar of chlorine, the brilliancy of the flame is much impaired, it becomes red, throws off much charcoal, and is soon extinguished.

Many bodies such as phosphorus and several of the metals, are spontaneously ignited by chlorine, and burn in it with much brilliancy. In these cases binary compounds result, some of which, like those of

Union with combustibles.

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* Sp. gr. of chlorine 2.25 or just $\frac{36}{16}$ths of 1 (the standard oxygen.)

oxygen, are possessed of acid properties: others are not acid: and such compounds with oxygen being called *oxides*, those which chlorine forms may be termed *chlorides*.

Formerly considered as compound.

215. Chlorine was once regarded as composed of oxygen and muriatic acid; a fallacy arising from the presence of water, and which will be rendered more intelligible under the head *Muriatic Acid.*

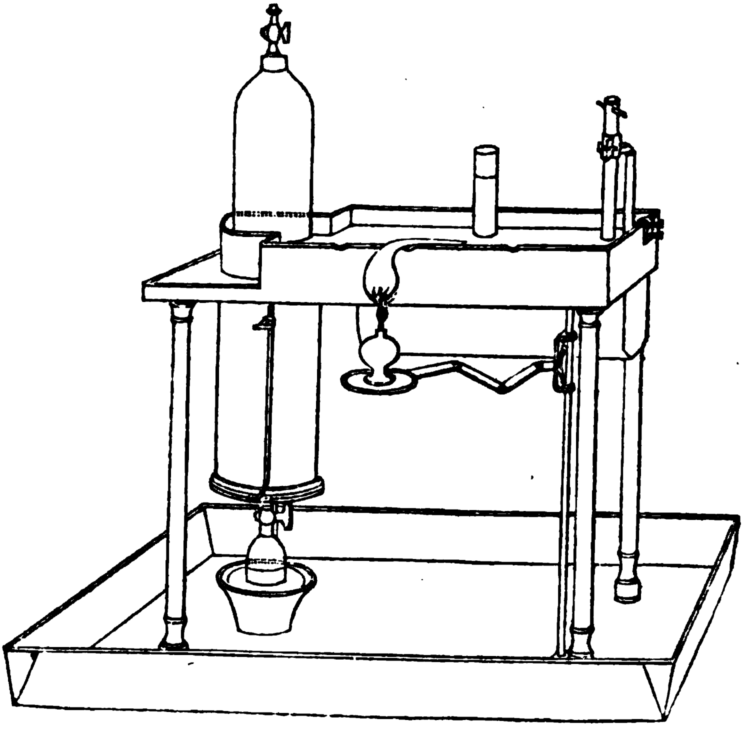
216. Chlorine and oxygen unite in three proportions, forming an oxide and two acids.

Union of chlorine with oxygen.

217. *Oxide* of *Chlorine*, or *Euchlorine*, so called by its discoverer, Sir H. Davy (*Phil. Trans.* 1815,) from its very deep colour, may be obtained as follows: Upon 10 or 12 grains of *chlorate of potassa*, drop a small quantity of sulphuric acid, and stir the mixture with a platinum knife, having so adjusted the relative quantities of salt and acid that they may form together a yellow powder. Put this into a very small retort or bent tube, and by means of a water-bath, apply a temperature of 150°. Oxide of chlorine will pass off, and may be collected over quicksilver in small jars or tubes.

Mercurial apparatus for collecting gases.

218. Those gases which are absorbed by water, may, in most instances, be collected over mercury. The best form of the *Mercurio pneumatic apparatus*, is that contrived by Mr. Newman, (*Quarterly Journal*, Vol. i. p. 185.) It is a trough of cast-iron, supported by brass or iron legs, and having a small gasometer at one end. It is placed in a japanned iron-tray to collect the scattered mercury, as shown in the wood-cut.



Properties of oxide of chlorine.

219. Oxide of chlorine has an odour somewhat resembling that of chlorine, but much less irritating and disagreeable. Its taste is astringent, and not at all acid. It dissolves in water, forming a lemon-yellow solution.

When heated is decomposed with explosion and expansion composition.

220. When oxide of chlorine is gently heated, it is decomposed with explosion and expansion: two volumes are enlarged into three, of which two consist of oxygen, and one of chlorine; it is therefore composed (of 36 parts by weight of chlorine, combined with 32 of oxygen)*.

Composition of chloric acid.

221. *Chloric acid.* In the substance which has been thus called by its discoverer M. Gay-Lussac (*Annales de Chimie*, tom xci. p. 108,) the† (relative proportions of chlorine to oxygen are to each other as 36. to 40.) But it is a compound which cannot exist, independent of water or some base, and, therefore, may be compared to the *sulphuric* and some other acids, afterwards to be described.

Preparation.

Chloric acid may be prepared by passing a current of chlorine through a mixture of oxide of silver and water. Chloride of silver is produced, which is insoluble, and may be separated by filtration. The excess of chlorine, which the filtered liquor contains, is separable by heat, and the chloric acid dissolved in water remains. It is a sour, colourless liquid, producing peculiar compounds, afterwards to be described. It forms no precipitate in any metallic solution. The compounds may be called *chlorates.* The most remarkable of them have been long known under the name of *Oxymuriates.*

Properties.

Preparation and composition of perchloric acid.

222. *Perchloric* or *oxychloric acid*, is procured by distilling *oxychlorate* of *potassa* (547) with its own weight of sulphuric acid. It consists of (36. chlorine + 56. oxygen.) It does not exist independent of water, or a base, and has been but imperfectly examined.

The proper terms for the above acids of chlorine would be *Chlorous* and *Chloric* acids, the former producing *Chlorites* and the latter *Chlorates.*

◆

SECTION III. *Of Iodine.*

Process for obtaining Iodine.

223. IODINE is procured by the following process: Lixiviate powdered *kelp* with cold water. Evaporate the lixivium till a pellicle forms, and set aside to crystallize. Evaporate the mother liquor to dryness, and pour upon the mass half its weight of sulphuric acid. Apply a gentle heat to this mixture in the flask *a* of the *alembic* shown in the annexed figure, of which *b* is the head or capital, having a tube

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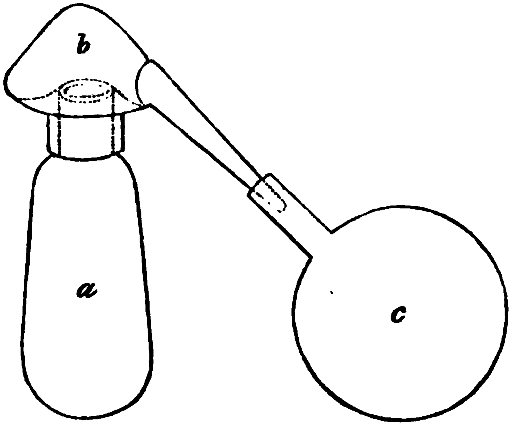
* The gas, originally called *Euchlorine* by Sir H. Davy, appears to be a mixture of chlorine with the compound above described, and not a definite compound of two volumes of chlorine and one volume of oxygen. Should it, however, upon more accurate inquiry, prove a definite combination, it might be termed *chlorous oxide*, and the above compound would then be *chloric oxide.*

† We have before remarked that the sp. gr. of chlorine (oxygen being 1) is = 2.25, if we also take the *atom* of oxygen = 1, then to find the atom of chlorine we have only to double the specific gravity, viz. 2.25 × 2 = 4.5, the same as deduced above, from the proportional weights of constituents. Moreover the atom of hydrogen being already stated, = 0.125 the atom of chlorine is evidently 36 times as great or = 4.5, i. e. the atoms of these 2 gases are as their specific gravity. (Sec. 212.)

issuing from it, and descending into the receiver *c*. Fumes of a violet colour arise and condense in the form of opaque crystals, having a metallic lustre, which are to be washed out of the head of the alembic with a small quantity of water, and quickly dried upon bibulous paper.



Iodine may likewise be obtained from soap-makers' *black ash* by a similar process; instead of evaporating the mother liquor to dryness, the quantity of iodine is sometimes greater when it is merely concentrated, mixed with excess of sulphuric acid, boiled, and filtered: the liquid is then mixed with its weight of powdered black oxide of manganese, and heated in an alembic, or flask with a tube attached to its neck, when the iodine sublimes as before.

This body was discovered in 1812, by M. Courtois, of Paris. Vauquelin (*Annales de Chimie*, tom. xc.,) Gay-Lussac (*ib.* xc.,) and Davy (*Phil. Trans.* 1814,) have fully investigated its properties.

Properties. Iodine has a bluish black colour; its lustre is metallic. It is a nonconductor of electricity. It is soft and friable. *Its specific gravity = 4.946. It produces a yellow stain upon the skin. Its smell resembles that of diluted chlorine; its taste is acrid. It is extremely volatile, and, at a temperature between 60° and 80°, produces a violet vapour. At 120° or 180° it rises more rapidly. At 220° it fuses, and produces copious violet-coloured fumes, which condense in brilliant plates, and acute octoëdrons. Like chlorine and oxygen, it is electronegative; and therefore attracted by the positive surface of the Voltaic pile. It renders vegetable colours yellow. It is very sparingly soluble in water, that liquid not holding more than $\frac{1}{7000}$ its weight in solution. The colour of the solution is yellow. It is much more soluble in spirit of wine, and in ether.

Combination with oxygen gas. 224. Iodine combines with oxygen and with chlorine, and gives rise to two acid compounds which have been called *Iodic*, or *Oxiodic*, and *Chloriodic* acid.

Iodic acid. *Iodic acid* (Davy, *Phil. Trans.* 1815.) This compound of oxygen and iodine cannot be obtained directly, for those bodies exert no mutual action. It is procured by acting upon oxide of chlorine by iodine.

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* The specific gravity of Iodine *vapour* is to that of Hydrogen, as 125 : 1 and this × by the atom of hydrogen (0,125) gives the atom of iodine thus 125 × 0, 125 = 15.625 atom Iodine.

For this purpose the iodine may be introduced into a small flask, and the oxide of chlorine disengaged upon it, from a proper mixture of chlorate of potassa and sulphuric acid with the precautions above pointed out (217,) or 100 grains of chlorate of potassa may be introduced into a small retort, with 400 grains of liquid muriatic acid of the sp. gr. 1. 1.105: annex to the retort a small globular receiver, having a bent tube issuing from it, and passing to the bottom of a small flask, containing about 50 grains of iodine; carefully apply the heat of a lamp to the retort, by which oxide of chlorine will be disengaged, and which will be decomposed and absorbed by the iodine. A compound is then formed, which consists of chloriodic and oxiodic acids. The former is separable by a gentle heat, the latter remains as a white, semitransparent, sour, and inodorous body, very soluble in water. It consists of 125 iodine, 40 oxygen.)*

Method of procuring iodic acid.

Composition.

225. *Chloriodic acid* is easily obtained by the direct action of chlorine upon iodine. They unite and form crystals of a deep orange colour, deliquescent, and easily fusible and soluble. The solution is sour. This compound contains (125 iodine, 36 chlorine.—Davy, *Phil. Trans.* 1814.

Chloriodic acid.

Composition.

It appears probable from the experiments of M. Gay-Lussac, that another chloride of iodine exists, in which 2 proportionals of iodine are united to 1 of chlorine; but these compounds have not yet been examined with sufficient precision, to enable us to speak certainly upon their composition.

◆

CHAPTER IV.

OF SIMPLE ACIDIFIABLE AND INFLAMMABLE SUBSTANCES.

226. The bodies belonging to this class are electro-positive, and consequently, when separated from their combinations with the substances described in the last chapter, by Voltaic electricity, they are attracted by the negative surface. With very few exceptions, they combine with the three supporters of combustion, already described, and of these compounds, one or more are acids. They are six in number:

Electro-positive.

1. Hydrogen.
2. Nitrogen.
3. Sulphur.
4. Phosphorus.
5. Carbon.
6. Boron.

◆

Section I. *Hydrogen.*

227. Hydrogen was first duly examined by Mr. Cavendish (*Phil.*

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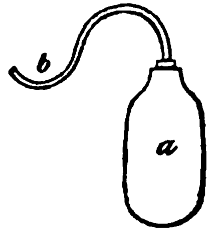
* The specific gravity of iodine vapour, as deduced from hydriodic acid, (oxygen being 1) is = 7.8125, near by and its atom is just double or 15.625, (the *atom* also, of oxygen being 1) —again 0.125 (atom hydrogen) × 125 = 15.625 (atom Iodine.)

Mode of procuring hydrogen. *Trans.* Vol. lvi.) It may be obtained by the action of iron or zinc upon dilute sulphuric acid. Some pieces of iron-wire, or of zinc, may be introduced into the flask *a*, and covered with sulphuric acid diluted with six times its bulk of water. The gas escapes by the bent tube *b*, which is inserted by grinding into the neck of the flask, and may be collected in the hydro-pneumatic apparatus.



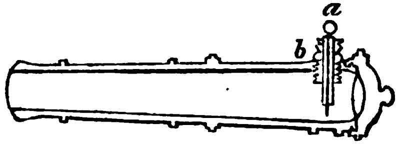
Hydrogen is an aëriform fluid, not absorbable by water. It has no

Character and Properties. taste, a slightly disagreeable smell, and may be respired for a short time, though it is instantly fatal to small animals. It is the lightest body known; and we therefore conveniently assume it as unity in speaking of the specific gravity of gases, as well as in referring to the

Weight. proportions in which bodies combine. 100 cubic inches weigh at mean temperature and pressure 2.118 grains. Its specific gravity is 0.0694, when common air is taken as 1.00, and 0.0625 when oxygen is = 1.00*.

228. Hydrogen is inflammable, and extinguishes flame. When pure, it burns quietly with a lambent blue flame at the surface in contact with air; but, if mixed with thrice its volume of air, it burns rapidly, and with detonation. In making this experiment, a strong phial, capable of holding about 6 ounces of water, may be employed; or the *inflammable air-pistol*, which admits of the mixture being fired by the electric spark.

Inflamable air pistol. This instrument consists of a cylinder of brass, about three-fourths of an inch diameter, and six inches long, in the form of a small cannon or pistol-barrel, properly mounted, and having a wire, *a*, passing through a tube of ivory, *b*, and not quite touching the interior of the cylinder, at the part usually occupied by the touch-hole; an electric spark communicated to this wire inflames the mixture of hydrogen and atmospheric air in its interior. It may be charged by previously filling it with dry sand, and emptying it out into a phial of hydrogen, which rises into the gun sufficiently mixed with air; the muzzle may be secured by a cork, which is expelled with much violence and a loud report, upon the inflammation of the gas.



229. The electrical air-gun, may be also charged, by holding it for a moment over the open jet of the following instrument always taking care that there is a due admixture of atmospheric air, otherwise the electric spark will not inflame it.

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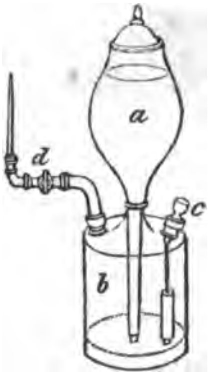
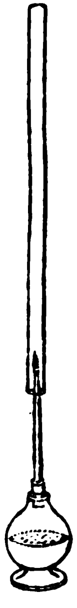
* We have seen that the specific gravity of hydrogen is 0,0625 when that of oxygen is taken = 1.00 now 0,0625 is just 16 times as small as 1,00 for 0,0625 × 16 = 1, again to find the atom of hydrogen the atom of oxygen being a pound = 1, we have only to double the specific gravity 0.0625 i. e. 0.0625 × 2 = 0.125 atom hydrogen. (Sec. 236.)



a is a funnel shaped vessel, fitting by a ground-joint into the three-necked bottle *b*; to the stopper *c* is annexed a brass wire, with a cylinder of zinc screwed upon its lower end; *d* is a tube furnished with a stopcock and jet-pipe; the capacity of the vessel *a* should be nearly equivalent to that of *b*, and may contain 3 or 4 pints. To charge this apparatus with hydrogen, *b* is three fourths filled with water, and the stopper *c* being removed, a quantity of sulphuric acid, previously diluted with its bulk of water, is poured in by a long funnel, so that it may remain at the bottom of the water which now fills the vessel. The stopper *c*, with its appended piece of zinc, is then put in, and the generated hydrogen forces the dilute acid into *a*, where its pressure serves to propel the gas through *d* whenever the stop-cock is opened; the acid, at the same time descending, produces a fresh portion of hydrogen by again acting upon the zinc. This instrument is useful where small quantities of hydrogen are required for burning, charging air-guns, and other purposes.

230. If 2 volumes of hydrogen and 1 of oxygen be burned in the phial or air gun, the explosion is extremely violent.



Musical tones during the combustion of hydrogen.

231. A current of hydrogen may be inflamed when issuing from a small aperture, and if a tube of 18 or 20 inches in length be held over the flame, a peculiar musical tone is produced. This effect is not peculiar to hydrogen, but is produced by a variety of other flames (Faraday, *Journal of Science and the Arts*, Vol. v.) and is referable to the succession of explosions produced by the combustion of the gas in the tube.

Gases have a powerful tendency to mix together.

232. The tendency which gaseous fluids have to become completely mixed under all circumstances, and as it were to penetrate each other, is well illustrated where hydrogen is employed. Thus, if two small phials, the one containing oxygen and the other hydrogen, be connected perpendicularly by a long glass tube, of small bore, it will be found, that although the hydrogen be uppermost, and much lighter than the oxygen, it will, in the course of a few hours, have perfectly mixed with the oxygen, and the gases will be found in equal proportions in both phials. Mr. Dalton has shown that gases, unlike other fluids, do not remain upon each other without admixture.—*Manchester Memoirs*, Vol. i. New Series.

233. Hydrogen, in consequence of its extreme lightness, is employed for filling air-balloons, and is elegantly applied to the purpose of obtaining instantaneous light in Volta's inflammable air-lamp.

Use of hydrogen as a blow-pipe.

234. The flame of hydrogen is occasionally employed for exciting intense heat; and it has been found, when mixed with oxygen and burned as the mixture issues from a small jet, to excite a temperature nearly equal to that of the arc of flame in the Voltaic circuit. A blow-pipe upon this construction was first made by Mr. Newman, at the suggestion of Mr.

Brooks, and afterwards improved, as to its safety, by Professor Cumming, of Cambridge.—*Journal of Science and the Arts*, i. 65 and ii. 380.

Union with oxygen gas.

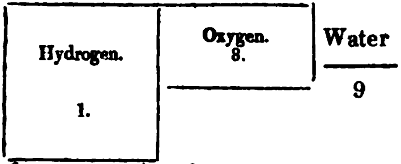
235. *Hydrogen and oxygen.*—When two volumes of hydrogen gas are mixed with one volume of oxygen gas, and the mixture inflamed in a proper apparatus by the electric spark, the gases totally disappear, and the interior of the vessel is covered with drops of pure water, equal in weight to that of the gases consumed.

Composition of water.

If pure water be exposed to the action of Voltaic electricity, it is resolved into two volumes of hydrogen, disengaged at the negative pole, and one volume of oxygen, disengaged at the positive pole; so that water is thus proved by synthesis, and by analysis, to consist of two volumes of hydrogen, combined with one volume of oxygen. The specific gravity of hydrogen compared with oxygen, is as 1 to 16, therefore the component parts of water by weight are,

1 Hydrogen.
8 Oxygen.
9 Representative number of water.

or thus,



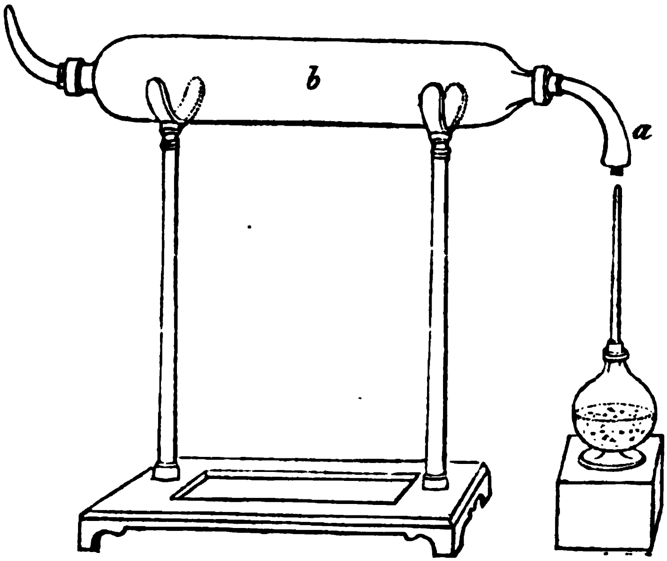
So that 100 parts of water consist of

88.89 Oxygen.
11.11 Hydrogen.
100,00

236. The experiments illustrating the composition of water, may be divided into synthetic and analytic. Among these the following may be selected:

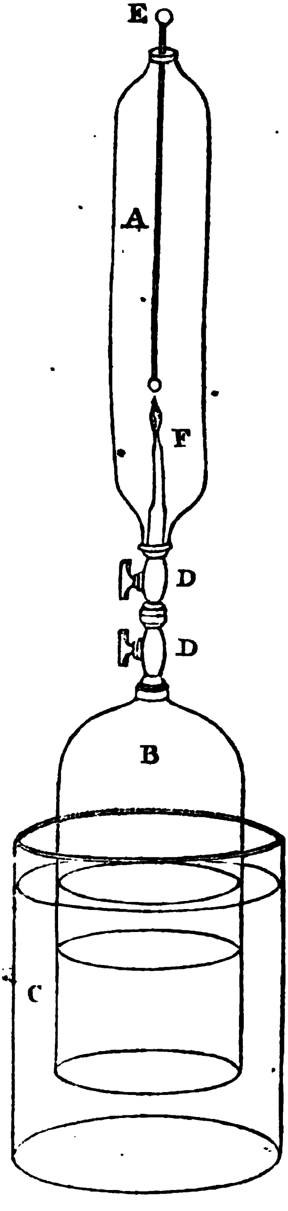
i. Burn a current of hydrogen under the funnel *a*, represented in the following wood-cut; by uniting with the oxygen of the atmosphere

Apparatus for shewing the formation of water.



it will produce aqueous vapour, which passing into the glass cylinder, *b*, will condense in drops.

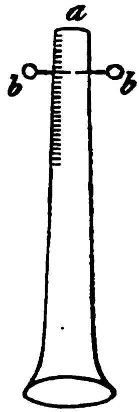
ii. The annexed woodcut represents an apparatus for showing the



production of water by burning a current of hydrogen in an atmos-

Burns with oxygen gas and forms water.

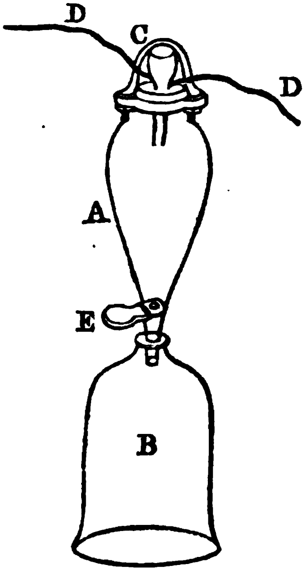
phere of oxygen. A is a glass cylinder, which after having been exhausted upon an air-pump, is filled with pure oxygen. B is a receiver of hydrogen immersed in the vessel of water C, by which the gas is compressed, so as to be urged through the capillary opening F, when the stop-cocks D D are open. E is a platinum wire by which the gas may be inflamed by an electric spark. It burns with the production of intense heat, and water is soon collected in drops upon the interior of the cylinder.



The mixture explodes.

iii. If two measures of pure hydrogen be mixed with one of pure oxygen, and detonated in the graduated glass tube *a*, standing over water, by an electric spark passed through the platinum wires *b b*, the gases will entirely disappear. If there be any excess of either of the gases, the portion in excess will remain unconsumed.

iv. the same experiment may be thus varied. A is very strong and thick glass vessel provided with a glass stop-cock E and with a ground stopper firmly secured by the wire C, through which the platinum wires D D pass. The vessel A being exhausted of air, is placed upon the bell-glass B, in the pneumatic trough, containing a mixture of pure oxygen and hydrogen in the above mentioned proportions (235). Upon opening the stop-cock, E, a quantity of the mixed gases passes into A, where, after having carefully closed the stop-cock, it may be inflamed by an electric spark passed through the platinum wires. At the instant of the detonation a vivid flame pervades the upper vessel, and it becomes lined with mois-

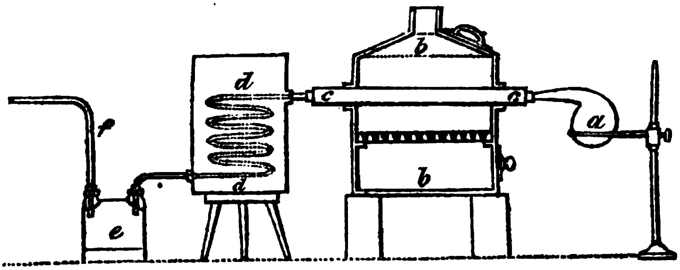


ture. If the stop-cock be again opened a fresh portion of the mixed gases enters, and may be inflamed as before.

Analysis of water by iron

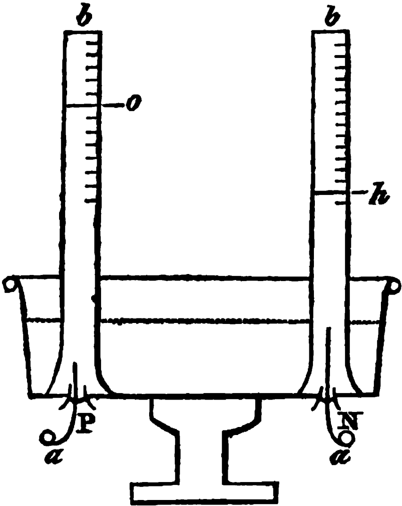
237. Water may be decomposed or resolved into its elements by a variety of processes, the most important of which are the following:

i. *a* is a glass retort, into which is introduced a given weight of water; *b b* a small furnace through which passes the earthen tube *c c*, which terminates in the spiral pewter tube *d d*, immersed in water. A given weight of pure iron wire, coiled up, is introduced into the tube *c*, and the whole made red hot; the water in *a* is then made to boil, and the vapour, on coming into contact with the red-hot iron, is in part decomposed; the oxygen is retained by the iron, and the hydrogen escaping through the tube *f*, may be collected as usual. Any decomposed portion of water is condensed in the worm-pipe *d*, and drops into the vessel *e*. After this experiment the iron will be found to have increased in weight; and if attention be paid to the quantity of water which has collected in *e*, and to the weight of the hydrogen gas evolved, it will be found that the weight gained by the iron, added to that of the hydrogen, will be equal to the weight of the water which has disappeared. Lavoisier concluded, from an experiment thus conducted, that water consisted of 85 *per cent.* by weight of oxygen, and 15 by weight of hydrogen; that is, that for every 15 grains of hydrogen evolved, 85 grains of oxygen were condensed by the iron.



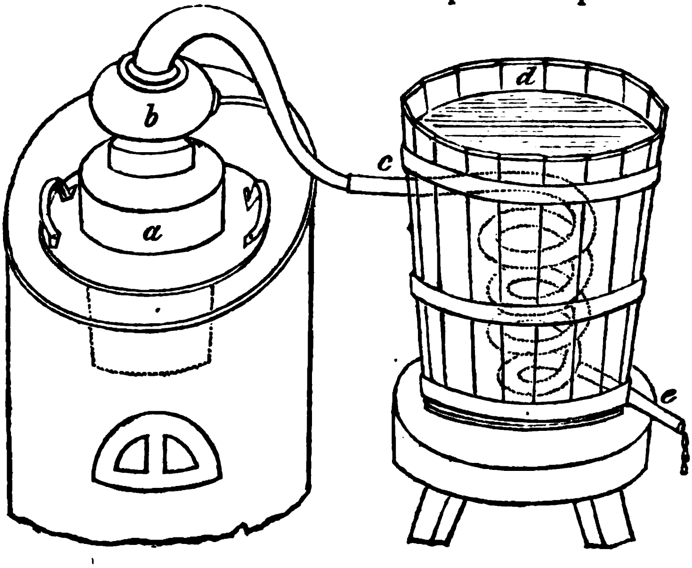
By Voltaic electricity.

ii. Decomposition by Voltaic electricity (137) best illustrates the composition of water, since it exhibits both the oxygen and hydrogen in the gaseous form. The woodcut overleaf represents a section of an apparatus for this purpose. It is a glass vessel containing water, having two wires of platinum, *a a*, passing through its bottom: over these are inverted the tubes *b b*, also filled with water. The wires are rendered positive and negative by connexion with a moderately-powerful Voltaic apparatus. Oxygen is evolved at the positive wire, and hydrogen at the negative wire, which gases rise into the tubes, and it is seen that one volume of oxygen, *o*, and two volumes of hydrogen, *h*, are the constant results. If these gases be mixed and detonated, pure water is again formed.



Heterogeneous contents.

238. Water, in its ordinary state, such as *spring* and *river water*, is always so far contaminated with foreign substances as to be unfit for many chemical purposes, and frequently, as will be more fully shown hereafter, even for domestic use. *Rain-water* is much more pure, but it always contains a portion of carbonic acid and of the elements of atmospheric air, besides appreciable traces of vegetable or animal matter; to the latter it owes its property of becoming putrid when kept. The distinction of water into *hard* and *soft* has reference to its less or greater purity. The impurities of water are separated by distillation, which process is usually conducted upon the large scale in a copper *boiler*, *a*, placed either in a portable furnace, or set in brickwork, according to its dimensions, to which is annexed a head, *b*, of the same material, or of pewter connected with the pewter *worm* *c*, which is immersed in the *worm-tub*, or *refrigerator*, *d*, its lower end passing out at *e*. The water in this vessel must always be retained of a low temperature to effect the condensation of the vapour in the spiral tube.



Distilled water, as commonly prepared, always affords minute traces of foreign matter, especially when subjected to Voltaic decomposition, and can only be considered as perfectly pure when re-distilled at a low temperature in silver vessels.

Properties.

Standard of specific gravity.

239. Pure water is transparent, and without either colour, taste, or smell. In consequence of the facility of obtaining it pure, it is assumed as a standard to which the relative weight of all other bodies may be compared, its specific gravity being called = 1.000, and hence the importance of estimating its weight with precision. At the temperature of 40° it is at its maximum of density, and at that temperature an English cubic foot weighs 437102.4946 grains (Thomson's *System*, Vol. ii. p. 12.) or 999.0914161 ounces avoirdupois, and a cubic inch 252.953 grains.

240. At the temperature of 32° water congeals into ice, which, if slowly formed, produces needles crossing each other at angles of 60° and 120°. The specific gravity of ice is 0.94. Exposed to the air, ice loses considerably in weight by evaporation.

Boiling point.

241. If water be exposed to heat in open vessels it boils, or is converted into steam, at 212°, the barometer being at 30 inches; but the boiling point of water varies considerably with the pressure (83.) The specific gravity of air being considered as = 1; that of steam is 0.6235. At mean pressure, and at the temperature of 212°, the bulk of steam is 1700 times greater than that of water.

Compressible.

242. Water is susceptible of compression, as was originally shown by Canton, and more lately by Mr. Perkins, who has estimated, in an ingenious series of experiments, the rate of its compression (*Phil. Trans.* 1820.) If submitted to very sudden compression, water becomes luminous, as has been shown by M. Desaignes.—Thenard, *Traité de Chimie*, i. 432.

243. Water enters into combination with a variety of substances, and is retained with various degrees of force: where it contributes to the regular form and transparency of crystallized bodies, it is termed *water of crystallization* (12.) In other cases the compounds which water forms with substances are called *hydrates*, as with many of the metallic oxides (520); in both cases it may be considered as one of the constituents of the bodies, for it exists in them in a definite proportion.

244. Water, which has been exposed to the atmosphere, always contains a portion of air, as may be proved by boiling it, or by exposing it under the exhausted receiver of the air-pump. To separate the air, the water must be boiled for about two hours. It absorbs oxygen gas in preference to atmospheric air or nitrogen, and when the air is expelled by boiling, the last portions contain more oxygen than those first given off.—Humboldt and Gay-Lussac, *Journal de Physique*, 1805.

Unites to an excess of oxygen.

245. M. Thenard has shown that water may be united to a considerable excess of oxygen by means of peroxide of barium. (*Quarterly Journal*, Vol. viii. p. 114.) The specific gravity of oxygenated water is about 1.45. It acts as a caustic upon the skin; detonates violently when dropped upon dry oxide of silver, or upon most of the metals finely divided. This singular compound may be termed *peroxide of hydrogen*: its properties, and the process for obtaining it, which is complex and circuitous, have been fully detailed by its discoverer, and

will be adverted to under the article *Peroxide of Barium*, Vol. ii., Section 5. Par. 630.

246. The following table exhibits the quantity of different gases which water is capable of absorbing at mean temperature and pressure, the water being previously deprived of all aëriform matter by long boiling.

GASES.	100 Volumes of Water absorb	AUTHORITY.
Oxygen	3.7 volumes	Dalton.
Chlorine	200	
Oxide of Chlorine	800	
Hydrogen	1.56	Henry.
Muriatic acid	50000. average	
Hydriodic acid		
Nitrogen	1.56	Henry.
Nitrous oxide	100	Ditto.
Nitric oxide	5	
Nitrous acid		
Ammonia	67000 average	
Sulphurous acid	3300	Thomson.
Sulphuretted hydrogen	100	Dalton.
Hydroguret of phosphorus	2.14	Henry.
Bi-hydroguret of phosphorus	12	Davy.
Carbonic oxide	2 average	
Carbonic acid	100	Dalton.
Carburetted hydrogen	12.5	Dalton.
Cyanogen	450	
Fluoboric acid	70000	John Davy.
Fluosilicic acid	35000	Saussure.

247. As hydrogen is the lightest known substance, it is assumed in this work as *unity*, in reference to the representative numbers of other bodies. The principle of numeric representation, or of equivalent or proportional numbers, has already been adverted to (50), and the following will be the representative numbers of the bodies described in the foregoing chapter, the number for oxygen being deduced from the composition of water (235), and of chlorine and iodine from the muriatic (248) and hydriodic acids (259).

Undecompounded Substances.	Proportional numbers.
Hydrogen	1
Oxygen	8
Chlorine	36
Iodine	125

Compounds.	Component Parts.			Representative Number.
Water......	1 proportional of hydrogen 1 ditto oxygen	= =	1 8	9.
Oxide of chlorine	4 proportionals of oxygen 1 ditto chlorine	= =	32 36	68.
Chloric acid	5 proportionals of oxygen 1 ditto chlorine	= =	40 36	76.
Perchloric acid......	7 proportionals of oxygen 1 ditto chlorine	= =	56 36	92.
Oxiodic acid	5 proportionals of oxygen 1 ditto iodine	= =	40 125	165.
Chloriodic acid......	1 proportional of chlorine 1 ditto iodine	= =	36 125	161.

Muriatic acid.

248. *Hydrogen and Chlorine.*—When equal volumes of these gases are mixed and exposed to light, they combine, and produce a sour compound commonly called *muriatic acid gas;* or, in conformity to more modern nomenclature, *hydrochloric acid gas.* If the above mixture be exposed to the direct solar rays, a detonation ensues, as was first remarked by M. M. Gay-Lussac and Thenard. (*Recherches Physico-Chymiques*, ii. 129.) It also detonates when exposed to the light of the Voltaic discharge, showing a curious analogy between electric and solar light; for ordinary artificial light does not accelerate the combination. BRANDE, *Phil. Trans.* 1820.

The best mode of showing the composition of muriatic acid, is to introduce into a small but strong glass vessel a mixture of the two gases, and to inflame them by the electric spark; no change of volume ensues, and muriatic gas results. The apparatus shown at page 334, may be used for this purpose.

Analysis of muriatic or hydro-chlorine acid.

249. Muriatic acid may be decomposed by the action of several of the metals. Potassium, for instance, absorbs the chlorine, and the hydrogen is evolved; muriatic acid gas thus affords half its volume of hydrogen. As the specific gravity of hydrogen to chlorine is as one to 36.0, muriatic acid will consist of 1 hydrogen + 36.0 chlorine, and its representative number will be 37.0.

Hydrogen.	Chlorine.		Muriatic Acid.
1	36.0	=	37.0

250. Muriatic acid may be readily procured by acting upon common salt by sulphuric acid; the evolved gas must be received over mercury. It was first obtained pure by Dr. Priestley, but its composition

was discovered by Scheele, and has since been most ably investigated by Davy.

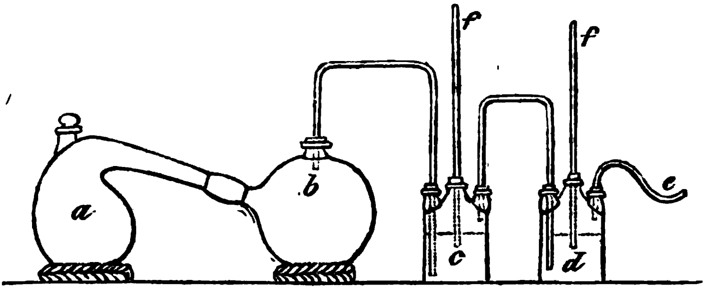
Properties.

251. Muriatic acid gas extinguishes flame. Its specific gravity, compared with hydrogen, is = 18.5; 100 cubic inches = 39.162 grains.*

Absorbed by water.

252. Muriatic acid gas is greedily absorbed by water, which takes up 480 times its bulk, and has its specific gravity increased from 1 to 1.210.

253. For saturating water with gases which are easily soluble in that fluid, we generally employ *Woulfe's apparatus*, one form of which is shown in the annexed cut. *a*, is a tubulated retort in which the materials, producing the gas or vapour, are contained; *b*, a receiver communicating by a bent tube with the three-necked bottle *c*, which is connected also by a tube with *d*. These bottles are about half filled with water, or any other fluid intended to be saturated with the gas; when that in *c* has become saturated, it passes into *d*, and afterwards through the tube *e*, which may be placed under the water, or mercury, in the pneumatic trough. In case absorption should take place in the vessels *a* or *b*, the pressure of the external air might force the water from *d* into *c*, and from *c* into the balloon *b*. This is prevented by the safety tubes *f f*, which dipping not more than half an inch under the surface of the water, allow a little air to enter, so as to compensate for the absorption. The different joints may be secured either by grinding, or by well-cut corks rendered tight by a mixture of drying oil and pipe-clay.



254. When muriatic acid is thus dissolved in water, it forms the *liquid muriatic acid* or *spirit of salt*, and may easily be procured by distilling a mixture of dilute sulphuric acid and common salt, as directed in the *London Pharmacopœia*. The most economical proportions are 32 parts of salt, and 22 of sulphuric acid, diluted with one third its weight of water. The retort containing these ingredients may be luted on to a receiver, containing twice the quantity of water used in diluting the sulphuric acid, and the distillation carried on in a sand-bath.

How obtained.

255. When this liquid acid is pure it is perfectly colourless, but it generally has a yellow hue arising from a little iron. When heated, the gaseous acid is evolved.

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* When the specific gravity of oxygen =1, that of muriatic acid gas will be 1.156; now to find the atom of muriatic acid, we have only to multiply its specific gravity by 4, i e. 1.156 × 4=4.625 the atom of muriatic acid, (when that of oxygen is taken=1), again the atom of muriatic acid is 37 times as great as that of hydrogen, for 0.125 × 37=4.625.

256. The following Table shows the quantity of real acid contained in 100 parts of liquid acid of different specific gravities.—Davy's *Elements*, p. 253.

Table showing the Quantity of real Acid in Liquid Muriatic Acid of different Specific Gravities. (Temperature 45° Fahr. Barometer 30.)

Specific Gravity.	100 Grains contain of Muriatic Acid Gas.	Specific Gravity.	100 Grains contain of Muriatic Acid Gas.
1.21	42.43	1.10	20.20
1.20	40.80	1.09	18.18
1.19	38.38	1.08	16.16
1.18	36.36	1.07	14.14
1.17	34·34	1.06	12.12
1.16	32.32	1.05	10.10
1.15	30.30	1,04	8.08
1.14	28.28	1.03	6.06
1 13	26.26	1.02	4.04
1.12	24.24	1.01	2.02
1.11	22.30		

Hydriodic acid.

257. *Hydrogen and Iodine* exert a slow action under ordinary circumstances; but when iodine is presented to nascent hydrogen, they readily unite, and produce a gaseous acid, the *hydriodic acid.* It is prepared by the action of moist iodine upon phosphorus, and must be received over mercury; which, however, soon acts upon and decomposes it, so that it should be transferred as speedily as possible into an exhausted vessel. In procuring it, it is convenient to use a small retort or bent tube, into the bulb of which is introduced the iodine, and a small stick of phosphorus placed in the neck above it, which can be shaken down upon the iodine when the beak of the tube or retort is placed under the inverted jar; a quantity of the gas is instantly and violently generated, and a further portion is obtained on applying the flame of a spirit lamp.

258. Hydriodic acid is colourless, very sour, and smells like muriatic acid*. Its specific gravity to hydrogen is as 63.00 to 1. 100 cubic inches = 133.4 grains.

259. Hydriodic gas is rapidly absorbed by water. The solution, exposed to a temperature below 260°, becomes concentrated by loss of water; at about 260° it boils, and may be distilled. The specific

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* These conclusions are obtained from the fact, that, hydriodic acid is composed of equal volumes of hydrogen and iodine vapour. The *specific gravity* of hydriodic acid is 3.9375 (or being =1), now four times this =15.75 the *atom* of this acid—again 15.75 is just 126 times 0, 125 the atom of hydrogen, (that of oxygen being =1).

gravity of the strongest liquid acid is 1.7. It becomes dark coloured when kept, in consequence of a partial decomposition, and it readily dissolves iodine, becoming of a deep brown colour.

The liquid hydriodic acid is best prepared by passing sulphuretted hydrogen through a mixture of iodine and water; sulphur is deposited, and on heating and filtering the liquor, a pure solution of hydriodic acid is obtained, which may be concentrated by evaporation.

260. That hydriodic acid gas consists of equal volumes of hydrogen and vapour of iodine is shown by the action of mercury, which by absorbing the iodine, evolves half a volume of hydrogen from one of the gas.

It is instantly decomposed by chlorine, which produces muriatic acid and the blue vapour of iodine is rendered evident. These gases often take fire on mixture.

It consists of........	1.56	hydrogen,	0.248 (nearly 2 atoms)
Hydriodic acid	98.44	iodine,	15.625 (1 atom)
	100.00		

It is to be noted that Thomson in his system of chemistry gives the composition of this acid from the same data,

Iodine	8.6804	15.625 (1 atom)
Hydrogen	0.0694	0.125 (1 atom)

SECTION II. *Nitrogen.*

How obtained. 261. THIS was first recognised as a distinct aëriform fluid, by Dr. Rutherford in 1772. (Thesis, *De aere Mephitico.*) It may be obtained by heating phosphorus in a confined portion of dry atmospheric air, which consists of nitrogen and oxygen; the phosphorus absorbs the latter, and the former gas remains. After repeated washing, it may be considered as pure. It may also be obtained by the action of moist sulphuret of iron upon atmospheric air.

Properties. 262. 100 cubic inches of nitrogen weigh 29.625 grains; so that its specific gravity, compared with hydrogen, is as 14[*] to 1. It is tasteless, inodorous, and insoluble in water. It does not support combustion and is fatal to animals; hence was called *azote*. It is not inflammable; but when its compounds are submitted to Voltaic decomposition, it is attracted by the negative pole.

263. *Nitrogen and Oxygen.*—These bodies unite in four proportions, and form the compounds called,

1. Nitrous oxide.
2. Nitric oxide.
3. Nitrous acid.
4. Nitric acid.

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[*] When the *specific gravity* of oxygen is taken as the standard, or =1, that of nitrogen will be 0.875, or $\frac{14}{16}$ of 1; again when the *atom* of oxygen is made 1, or the standard then twice the specific gravity of nitrogen will be its relative atom, thus, 0875×2=1.750 atom of nitrogen.

Nitrous oxide.

264. *Protoxide of Nitrogen*, or *Nitrous Oxide*, may be obtained by heating in a glass retort over an Argand lamp, the salt called *nitrate of ammonia*, to a temperature of about 420°. The gas which passes off may be collected over warm water, and is *nitrous oxide*.[*] 100 cubic inches weigh 46.574 grains; its specific gravity, therefore, to hydrogen is as 22 to 1.

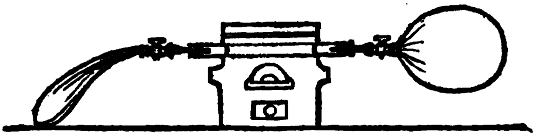
The taste of this gas is sweet, and its smell peculiar, but agreeable.

It is easily absorbed by water, which takes up about its own bulk, and evolves it unchanged when heated.

Its singular effects, resembling intoxication, when respired, were first ascertained by Sir H. Davy. (*Researches Chemical and Philosophical, chiefly concerning Nitrous Oxide*. London, 1800.) The experiment of breathing this gas, however, cannot be made with impunity, especially by those who are liable to a determination of blood to the head.

265. Nitrous oxide supports combustion, and a taper introduced into it has its flame much augmented and surrounded by a purplish halo. Phosphorus and sulphur, when introduced in a state of vivid ignition into this gas, are capable of decomposing it, and burn with the same appearance nearly as in oxygen; but, if when put into the gas, they are merely burning dimly, they then do not decompose it and are extinguished, so that they may be melted in the gas, or even touched with a red hot wire without inflaming. Charcoal, and many of the metals, also decompose nitrous oxide at high temperatures.

266. At a red heat this gas is decomposed and converted into nitrogen and nitric oxide, undergoing at the same time an increase of bulk. For experiments of this kind the following simple apparatus may be used: It consists of two bladders, one of which is filled with the gas, and the other empty attached to the extremities of a porcelain tube which traverses the body of a furnace. The bladders are supplied with stop-cocks, and the gas is squeezed from one to the other when the tube is red hot.



Analysis of nitrous oxide.

267. The best analysis of this gas is effected by detonation with hydrogen; one volume of nitrous oxide requires one volume of hydrogen. This mixture fired by the electric spark, produces water, and one volume of nitrogen remains. Now, as one volume of hydrogen takes half a volume of oxygen to form water, nitrous oxide must consist of two volumes of nitrogen and one volume of oxygen; these three volumes being so condensed in consequence of chemical union, as only to fill the

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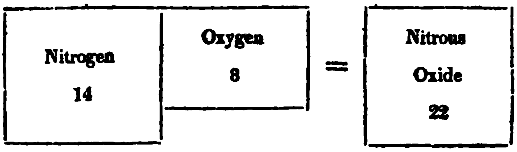
[*] Protox of nitrogen, when oxygen is the standard has its specific gravity=1.375; this multiplied by 2 gives 2.75 for the atom of nitrogen, when oxygen is also the atomic standard—now 2.75 is just 22 times 0.125 (the atom of hydrogen, for the same standard.)

space of two volumes. The specific gravity of nitrogen compared with oxygen, is as 14 to 16; nitrous oxide, therefore, consists of

14 Nitrogen
8 Oxygen
—
Number for nitrous oxide, = 22

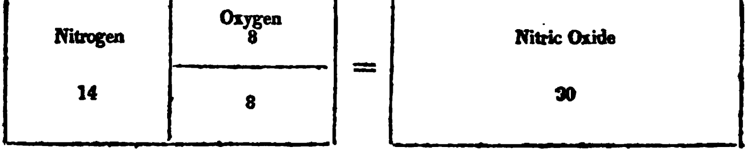
or,



268. *Nitric oxide, deutoxide of nitrogen,* or *nitrous gas,* is usually obtained by presenting certain substances to nitric acid, which abstract a portion of its oxygen, leaving the remaining elements in such proportions as to constitute the gas in question; for this purpose some copper filings may be put into a gas bottle (227) with nitric acid, diluted with thrice its bulk of water; an action ensues red fumes are produced, and there is a copious evolution of the gas, which may be collected and preserved over water. The first portions should be rejected as containing nitrogen and nitrous acid gas. Nitric oxide is presently recognised by the red fumes which it produces when brought into the contact of air.

* Its specific gravity to hydrogen is as 15 to 1. 100 cubic inches weigh 31.755 grains. When it has been washed with water it is not acid, as may be proved by the colour of litmus remaining unchanged by it. It extinguishes most burning bodies, but phosphorus readily burns in it, if introduced in intense ignition.

269. It is not altered by a red heat, nor does it detonate when mixed with hydrogen, and subjected to the electric spark; but it may be decomposed by the action of some of the metals at high temperatures, which absorb its oxygen. One volume of nitric oxide is thus resolved into equal volumes of oxygen and nitrogen. If, therefore, we call nitrous oxide a compound of 1 proportional of nitrogen + 1 oxygen, then nitric oxide may be considered as consisting of 1 nitrogen + 2 oxygen, or by weight, 14 nitrogen + 16 oxygen, and its symbol will stand thus:



270. A piece of glowing charcoal plunged into nitric oxide gas is presently extinguished, but if it be passed through a porcelain tube containing red-hot charcoal, nitrogen and carbonic acid and oxide are produced.

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* When the specific gravity of oxygen = 1, the deutox. nitrogen = 0.9375—this multiplied by 4 gives 3.75 for its atom, (atom of oxygen being = 1)—further 3.75 is just 30 times, 125 (the atom of hydrogen.)

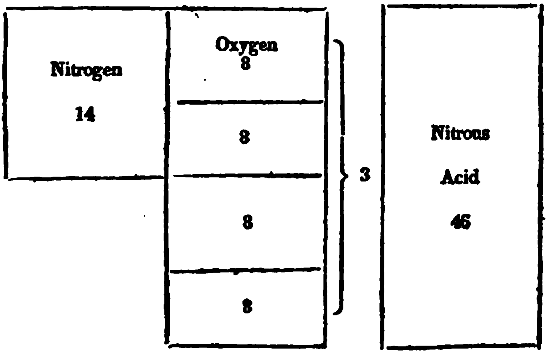
271. *Nitric Oxide and Chlorine*, when both are perfectly dry, exert no mutual action, but the presence of water causes an immediate change; it is decomposed, and, furnishing oxygen to the nitric oxide, and hydrogen to the chlorine, nitrous acid and muriatic acid gases are generated. It was the presence of water which misled those, who thought that the red fumes produced by mixing nitric oxide and chlorine not carefully dried, resulted from the existence of oxygen in chlorine.

272. Gay-Lussac has concluded from his experiments that there exists a compound of nitrogen and oxygen intermediate between nitric oxide and nitrous acid, which he has termed *per-nitrous acid*, but to which the term *hyponitrous acid* is more applicable. He considers it as a compound of 1 proportional of nitrogen, and 3 of oxygen; but the existence of such a compound can scarcely be considered as accurately demonstrated.

273. *Nitrous Acid Gas.*—When nitric oxide is presented to oxygen, the two gases combine, and a new gaseous compound of a deep orange colour results. This compound is not easily examined, because it is absorbed both by quicksilver and water, so that we are obliged to resort to exhausted glass vessels for its production. When we thus mix two volumes of nitric oxide with one volume of oxygen, the gases become condensed to about half their original volume, and form *nitrous acid gas.*

This gas supports the combustion of the taper, of phosphorus, and of charcoal, but extinguishes sulphur. It is readily absorbed by water forming a green sour liquid. Its specific gravity to hydrogen is as 23 to 1, and 100 cubic inches weigh 48.69 grains.*

274. It is obvious that this nitrous acid gas must consist of 14 nitrogen + 32 oxygen, and therefore, its number is 46; for nitric oxide is composed of equal volumes of nitrogen and oxygen, and one additional volume of oxygen, or two proportionals by weight are added to form nitrous acid.



275. If the mixture of nitric oxide and oxygen be made over water, in the above proportions, and if the gases be perfectly pure, complete

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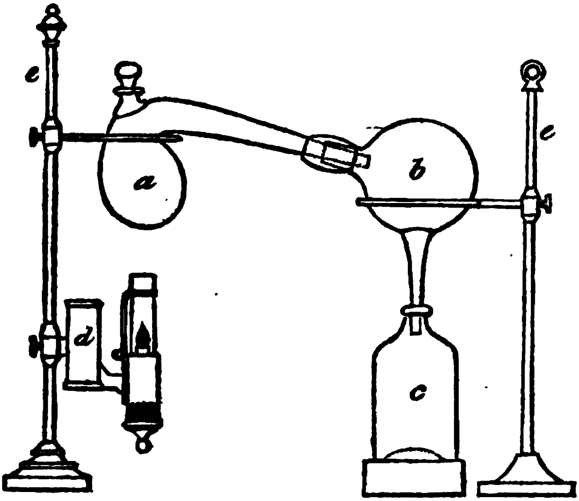
* Specific gravity of oxygen being =1; that of nitrous acid gas will be 2.875, this multiplied by 2 will give 5.75 for the atom when that of oxygen =1, also, 5,75 is just 46 times 0,125 (the atom of hydrogen.)

absorption takes place; but if either the oxygen or nitric oxide contain uncombined nitrogen it will remain unabsorbed.

276. *Nitric Acid.*—The fourth compound of nitrogen with oxygen is the nitric acid; the nature of which was first demonstrated by Mr. Cavendish in 1785. (*Phil. Trans.*) It is usually obtained by the distillation of purified nitre with sulphuric acid, of which materials different proportions are employed. The nitric acid of commerce, which is generally red and fuming in consequence of the presence of nitric oxide, is procured by the distillation of two parts of nitre with one of sulphuric acid; these proportions afford about one part of orange-coloured nitric acid of the specific gravity of 1.48. Upon the large scale 112 lbs. of nitre, and 56 of sulphuric acid yield from 50 to 52 lbs. of nitric acid. Some manufacturers employ three parts of nitre and two of sulphuric acid, and the *London Pharmacopœia* directs equal weights, by which a nearly colourless nitric acid is afforded.

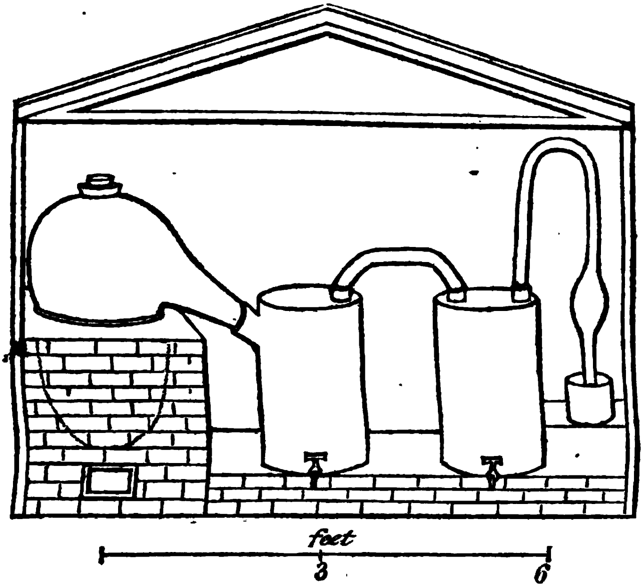
It will appear by referring to the article *Sulphuric Acid*, that it contains in its liquid state one proportional of dry acid, and *one* of water; whereas liquid nitric acid contains one proportional of dry acid, and *two* of water; hence the requisite excess of sulphuric acid, where colourless and perfect nitric acid is to be obtained; hence too the red colour of the acid of commerce in consequence of the smaller quantity of sulphuric acid generally used by the manufacturer. This will be more apparent by reference to the article *Bi-sulphate of Potassa.*

The distillation of nitric acid may be conducted upon the small scale in a tubulated glass retort *a*, with a tubulated receiver *b*, passing into the bottle *c*. The requisite heat is obtained by the lamp *d*, and the whole apparatus supported by the brass stands with sliding rings *e e*.



Preparation of nitrous acid. But the manufacturer who prepares nitric acid upon a large scale, generally employs distillatory vessels of stone-ware. The following wood-cut represents the arrangement of the distillatory apparatus, employed at Apothecaries' Hall, for the production of common *aqua-*

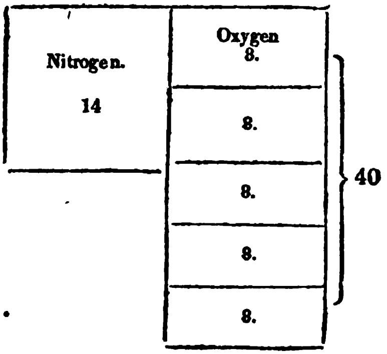
fortis; it consists of an iron pot, set in brick-work, over a fire-place; an earthenware head is luted upon it, communicating with two receivers of the same material, furnished with earthenware stop-cocks, the last of which has a tube of safety dipping into a basin of water.



277. The nitric acid of commerce, as obtained by the above processes, is always impure, and muriatic and sulphuric acids may usually be detected in it. The former may be separated by *nitrate of silver*, and the latter by a very dilute solution of *nitrate of baryta.* To obtain *pure nitric acid*, therefore, add to that of commerce a solution of nitrate of silver as long as it produces any white precipitate; and when this has subsided, pour off the clear liquor, and add, in the same way, the nitrate of baryta; then distil the acid, and it will pass over perfectly pure. For pharmaceutical purposes, the ordinary acid is generally sufficiently pure. If, however, pure nitre, and pure sulphuric acid be employed in its production, and the latter not in excess, there is little apprehension of impurity in the resulting acid,

The nitric acid is a colourless liquid, extremely sour and corrosive. Properties of nitric acid.
Its specific gravity is 1.42; it always contains water, which modifies its specific gravity. At 250° it boils and distils over without change. Specific gravity.
At—40° it congeals. It absorbs water from the air, and its bulk is thus increased, while its specific gravity is diminished. It is usually coloured by nitrous acid gas, which it evolves when heated.

278. Nitric acid in its dry state, that is, as it exists combined with metallic oxides in the salts called *nitrates*, may be regarded as composed of one proportional of nitrogen = 14, and 5 of oxygen = 40, and this will be the symbol representing its composition.



Consequently, the representative number of *dry* nitric acid is 54.0. But in its liquid state it always contains water; and when in this state its specific gravity is 1.5, it may be regarded as a compound of one proportional of dry acid and two of water, which may be numerically expressed thus:

Acid. Water.
54. + 17 = 74.0 liquid acid.

279. The following Table drawn up by Dr. Ure, exhibits the quantity of real acid in the liquid acid of different densities:—*Quarterly Journal*, iv. 297.

Quantity of real acid.

Specific Gravity.	Acid in 100.	Specific Gravity.	Acid in 100.	Specific Gravity.	Acid in 100.
1.5000	79.700	1.3783	52.602	1.1833	25.504
1.4980	78.903	1.3732	51.805	1.1770	24.707
1.4960	78.106	1.3681	51.068	1.1709	23.910
1.4940	77.309	1.3680	50.211	1.1648	23.113
1.4910	76.512	1.3579	49.414	1.1587	22.316
1.4880	75.715	1.3529	48.617	1.1526	21.519
1.4850	74.918	1.3477	47.820	1.1465	20.722
1.4820	74.121	1.3427	47.023	1.1403	19.925
1.4790	73.324	1.3376	46.226	1.1345	19.128
1.4760	72.527	1.3323	45.429	1.1286	18.331
1.4730	71.730	1.3270	44.632	1.1227	17.534
1.4700	70.933	1.3216	43.835	1.1168	16.737
1.4670	70.136	1.3163	43.038	1.1109	15.940
1.4640	69.339	1.3110	42.241	1.1051	15.143
1.4600	68.542	1.3056	41.444	1.0993	14.346
1.4570	67.745	1.3001	40.647	1.0935	13.549
1.4530	66.948	1.2947	39.850	1.0878	12.752
1.4500	66.155	1.2887	39.053	1.0821	11.955
1.4460	65.354	1.2826	38.256	1.0764	11.158
1.4424	64.557	1.2765	37.459	1.0708	10.361
1.4385	63.760	1.2705	36.662	1.0651	9.564
1.4346	62.963	1.2644	35.865	1.0595	8.767
1.4306	62.166	1.2583	35.068	1.0540	7.970
1.4269	61.369	1.2523	34.271	1.0485	7.173
1.4228	60.572	1.2462	33.474	1.0430	6.376
1.4189	59.775	1.2402	32.677	1.0375	5.579
1.4147	58.978	1.2341	31.880	1.0320	4.782
1.4107	58.181	1.2277	31.083	1.0267	3.985
1.4065	57.384	1.2212	30.286	1.0212	3.188
1.4023	56.587	1.2148	29.489	1.0159	2.391
1.3978	55.790	1.2084	28.692	1.0106	1.594
1.3945	54.993	1.2019	27.895	1.0053	0.797
1.3882	54.196	1.1958	27.098		
1.3833	53.399	1.1895	26.301		

280. Nitric acid may be decomposed by passing its vapour through a red hot porcelain tube; oxygen is given off, nitrous acid gas is produced, and a quantity of diluted acid passes over into the receiver, having escaped decomposition; so that it is thus proved to consist of nitrous acid gas, oxygen and water.

For experiments of this kind the form of apparatus, described for the decomposition of water by iron, may be employed (Sec. 237), omitting the condensing worm-pipe.

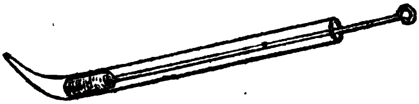
Composition of nitric acid.

The nature of nitric acid was first synthetically demonstrated by Mr. Cavendish, who passed electric sparks through a portion of atmospheric air, or through a mixture of one part of nitrogen and two of oxygen, confined over mercury. After some time the mixture diminished in bulk, and, on admitting a little water, an acid solution was obtained, which afforded chrystals of nitre when saturated with potassa.

281. *Nitro-muriatic Acid.*—This term has been applied to the *Aqua Regia* of the alchemists. When nitric and muriatic acids are mixed, they become yellow, and acquire the power of readily dissolving gold, which neither of the acids possessed separately. This mixture evolves chlorine, a partial decomposition of both acids having taken place, and water, chlorine, and nitrous acid gas, are thus produced; that is, the hydrogen of the muriatic acid abstracts oxygen from the nitric to form water: The result must be chlorine and nitrous acid.—Davy, *Journal of Science and the Arts*, Vol. i. p. 67.

282. *Nitrogen and Chlorine.*—*Chloride of Nitrogen.*—These gases do not unite *directly*, but the compound may be obtained by exposing a solution of *nitrate* or *muriate of ammonia* to the action of chlorine, at a temperature of 60° or 70°. The gas is absorbed, and an oil-like fluid, heavier than water, is produced. It was discovered by M. Dulong, in 1812.—*Annales de Chimie*, Vol. lxxxv.

The simplest mode of obtaining this compound, consists in filling a perfectly clean glass basin with a solution of about one part of sal-ammoniac in twelve of water, and inverting into it a tall jar of chlorine. The saline solution is gradually absorbed and rises into the jar, a film forms upon its surface, and it acquires a deep-yellow colour; at length small globules, looking like yellow oil, collect upon its surface, and successively fall into the basin beneath, whence they are most conveniently removed by drawing them into a small and perfectly clean glass syringe, made of a glass tube drawn to a pointed orifice, and having a copper wire with a piece of clean tow wrapped round it for a piston; in this way a globule may be drawn into the tube, and transferred to any other vessel.



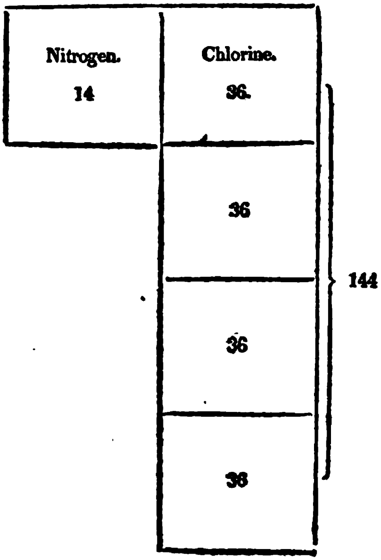
Its specific gravity is 1.65; it is not congealed by cold. Its odour is irritating and peculiar; it very soon evaporates when exposed to air. This substance is dangerously explosive, and is decomposed with violent detonation by many combustibles, especially phosphorus, and fixed oils.

In making these experiments, a small globule of the compound, about the size of a mustard-seed, should be cautiously transferred to a clean porcelain basin, half filled with water; a very small piece of phosphorus, fixed to the end of a long stick, or a long rod with the extremity dipped in oil may be then brought into contact with the globule, which instantly explodes, dispersing the water, and breaking the basin. At 160° it distils without change, but at 212° explodes, and is decomposed. It was submitted to the action of 125 different substances, by Messrs. Porret and Wilson, of which the following caused it to explode:

Phosphorus.
Phosphuret of lime.
Caoutchouc.
Myrrh.
Palm-oil.
Whale-oil.
Linseed-oil.
Olive-oil.
Oil of turpentine.
Naptha.
Liquid ammonia.
Phosphuretted hydrogen.
Nitric oxide.*

Composition of chloride of nitrogen.

Alcohol quietly changes it into a white substance. Mercury absorbs the chlorine and evolves nitrogen. It yields, by decomposition, 1 volume of nitrogen and 4 of chlorine; and as the specific gravity of nitrogen to chlorine is as 14 to 36.0, so it may be said to consist of 1 proportional of nitrogen + 4 proportionals of chlorine, or $\overset{N}{14} + \overset{C}{144}$, by weight, and its number will be 158.



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* The metals, resins, and sugar did not cause it to explode.—Nicholson's *Journal*, Vol. xxxiv.

In the state of vapour, it is probable that the five volumes of aëriform matter which it affords by decomposition, are condensed into one, since its decomposition by mercury is not attended by any change of its volume.

283. *Nitrogen and Iodine.*—A compound of these bodies may be procured by pouring a solution of ammonia upon a very small quantity of iodine. Hydriodic acid is one product, and the other a brown powder, which detonates upon the slightest touch, and is resolved into nitrogen and iodine. It may be collected by pouring off the liquid, and placing it, while moist, in small parcels upon bibulous paper, where it must be suffered to dry spontaneously. When it detonates, the purple fumes of iodine are perceptible. When left exposed to air it gradually evaporates.

Ammonia.

284. *Nitrogen and Hydrogen—Ammonia; or Volatile Alcali.*—This gaseous compound may be obtained by heating a mixture of *quicklime* and *muriate of ammonia.* Two parts of dry quicklime and one of muriate of ammonia may be introduced into a small glass retort, and, upon the application of a gentle heat, the gas passes over. It must be collected over mercury. It is permanently elastic at common temperatures, extremely pungent and acrid, but when diluted by mixture with common air, agreeably stimulant. It converts most vegetable blues to green, and the yellows to red, properties which belong to the bodies called *alcalis.* Ammonia, therefore, has been termed *volatile alcali.*

Specific gravity.

[*] *Its specific gravity to hydrogen is as 8.5 to 1; 100 cubical inches weighing 18 grains. It extinguishes flame, but forms an inflammable* mixture with common air and with oxygen.

285. Water, at the temperature of 60°, takes up 670 times its volume of ammonia; its bulk is increased, and its specific gravity diminished: that of a saturated solution is 0.875, water being 1.000. The following Table shows the quantity of ammonia in solutions of different specific gravities.—Davy's *Chem. Phil.* p. 268.

100 Parts of Sp. Gr.		Of Ammonia.	100 Parts of Sp. Gr.		Of Ammonia.
†*8750	Contain	32.50	9435	Contain	14.53
8875		29.25	9476		13.46
9000		26.00	9513		12.40
9054*		25.37	9545		11.56
9166		22.07	9573		10.82
9255		19.54	9597		10.17
9326		17.52	9619		9.60
9385		15.88	9692*		9.50

The usual state in which ammonia is employed is in solution, both in chemistry and medicine. This solution bears the name of *Liquor Ammoniæ* in the *London Pharmacopœia.* It may be obtained by passing the gas into water in a proper apparatus (253,) or by distilling over the water and gas together.

Preparation of liquor Ammonia.

The following process, recommended by Mr. R. Philips, answers well. On 9 ounces of well-burned lime pour half a pint of water, and when it has remained in a well-closed vessel for about an hour, add 12 ounces of muriate of ammonia in powder and three pints and a half of boiling water; when the mixture has cooled, pour off the clear portion, and distil from a retort 20 fluid ounces. The specific gravity of this solution, which is sufficiently strong for most purposes, is 0.954—*Remarks on London Pharmacopœia*, p. 34.

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[*] When sp. gr. ox. =1, that of ammonia will be 0.53125; this multiplied by 4 will give the atom of ammonia =2.125, and this atom is just 17 times the atom of hydrogen, (0.125.)

[†] The three results marked by the asterisk, were gained by experiments, the other numbers by calculation.

The specific gravity of the officinal solution directed in the *Pharmacopœia*, is 0.960.

Liquid ammonia should be preserved in well-stopped glass bottles, since it loses ammonia and absorbs carbonic acid, when exposed to air. When heated to about 140°, ammonia is rapidly given off by it; when concentrated it requires to be cooled to — 40° before it congeals, and then it is apparently inodorous.

If a piece of ice be introduced into a jar of ammonia standing over quicksilver, it melts with great rapidity, and liquid ammonia is produced.

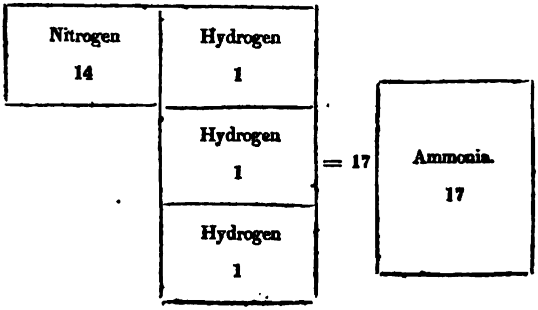
Analysis of ammonia.

286. Dr. Henry (*Phil. Trans.* 1809,) first observed that a mixture of ammonia and oxygen gas might be fired by an electric spark, and this property furnishes a means of analyzing the alcaline gas. Electricity also decomposes ammoniacal gas. If a succession of electrical sparks be passed through a small portion of the gas confined in a proper tube over quicksilver, it will increase to about twice its original bulk, and lose its easy solubility in water. If the gas thus expanded be mixed with from one-third to one-half its bulk of oxygen, and an electric spark passed through the mixture, an explosion takes place, attended by considerable diminution. Note the amount of the diminution, divide it by 3, and multiply the product by 2. The result shows the quantity of hydrogen. Thus, suppose 10 measures of ammonia, expanded by electricity to 18, and that, after adding 8 measures of oxygen gas, we find the whole (= 26 measures,) reduced by firing to 6 measures, the diminution will be 20. Then 20 ÷ 3 = 6.66 and 6.66 × 2 = 13.32 measures of hydrogen gas from 10 of ammonia; and 18 — 13.32 = 4.68 for the nitrogen gas contained in the product of electrization. Therefore, 10 measures of ammonia have been destroyed and expanded into

13.32 measures of hydrogen gas,
4.68 - - - - nitrogen gas.

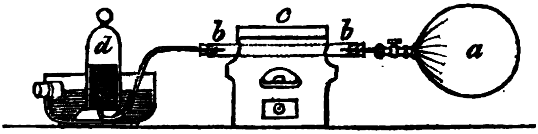
HENRY'S *Elements*, 7th edit. Vol. i. p. 233.

It appears probable that one volume of ammonia is resolved by electric decomposition into two volumes of a mixture of hydrogen and nitrogen, consisting of three volumes of hydrogen and one volume of nitrogen; hence the following symbols will represent the composition and volume of ammonia:



When ammonia and oxygen are detonated, the nitrogen is oxidized as well as the hydrogen; hence, if excess of oxygen be used, the whole of the ammonia disappears, and nitrate of ammonia is formed.

Ammonia is decomposed by passing it through a red-hot iron tube; it suffers expansion, and is resolved into hydrogen and nitrogen gases, furnishing a singular instance of change of properties in consequence of chemical combination. *a* is a bladder filled with ammonia which may be passed through the iron tube *b*, placed in the furnace *c*; the gas is decomposed, and hydrogen and nitrogen may be collected over the water in *d*.



Ammonia is also decomposed when passed over black oxide of manganese, heated red-hot in a porcelain tube; the results are water and nitrous acid gas; nitrate of ammonia is also often formed.

287. Ammonia is produced synthetically during the decomposition of many animal substances; it is also formed during the violent action of nitric acid upon some of the metals; and by moistened iron-filings exposed to an atmosphere of nitrogen; in these cases the nascent gases unite so as to form a portion of ammonia. **Synthesis.**

288. Ammonia combines with the acids, and produces a class of salts which, with very few exceptions, are soluble in water, and which evolve the odour of ammonia when mixed with lime or with pure potassa. These salts are, for the most part, entirely dissipated, and, generally speaking, decomposed by heat. **Salts of ammonia.**

289. *Ammonia and Chloric Acid—Chlorate of Ammonia* is formed by saturating chloric acid with carbonate of ammonia. It forms very soluble acicular crystals, of a sharp taste, which detonate when thrown upon hot coals. It probably consists of 1 proportional of each of its components, or 17 ammonia + 76 chloric acid.

290. *Iodate of Ammonia* forms small indeterminate crystals; when heated they are decomposed into oxygen, nitrogen, water, and iodine. Their composition has not been ascertained.

291. *Ammonia and Chlorine.*—When these gases are mixed, a partial decomposition of the former ensues. On mixing 15 parts of chlorine and 40 of ammonia, 5 parts of nitrogen are liberated, and muriate of ammonia is formed. If the gases be perfectly dry, considerable heat is evolved, and a flame is perceived to traverse the vessel in which the experiment is made.

292. *Ammonia and Muriatic Acid—Muriate of Ammonia—Sal Ammoniac*—This salt may be produced directly by mixing equal volumes of ammonia and muriatic acid, when an entire condensation ensues. **Muriate of ammonia.**

The specific gravity of ammonia to muriatic acid is as 8.5 to 18.5; therefore, muriate of ammonia consists of 18.5 muriatic acid + 8.5 ammonia.

Ammonia	Muriatic Acid.	
8.5	18.5	= 27.

Muriate of ammonia was formerly imported from Egypt, where it was obtained by burning the dung of camels; it is now abundantly prepared on the Continent and in this country. Its preparation will be hereafter described. When obtained by evaporation from its solution in water, it forms octoëdral, prismatic, and plumose crystals; but, in commerce, it usually occurs, as procured by sublimation, in white cakes, hard, and somewhat elastic, and in this compact state it requires for solution 3.25 parts of water at 60°. When heated it sublimes without decomposition in the form of white vapour. Its specific gravity composed with water is = 1.45 (Dr. Watson.)

Sal-ammoniac is used in the arts for a variety of purposes, especially in certain metallurgic operations. It is used in tinning, to prevent the oxidation of the surface of copper; and small quantities are consumed by dyers. Dissolved in nitric acid, it forms the *aqua regia* of commerce, used for dissolving gold, instead of a mixture of nitric and muriatic acids (281).

Native. 293. *Native Muriate of Ammonia* occurs massive and crystallized, in the vicinity of volcanoes, and in the cracks and pores of lava near their craters. It has thus been found at Etna, and at Vesuvius, in the Solfaterra near Naples, and in some of the Tuscan Lakes. An efflorescence of native sal-ammoniac is sometimes seen upon pit-coal. Its colour varies from the admixture of foreign matter, and it is frequently yellow from the presence of sulphur. It is said that considerable quantities of native sal-ammoniac are also found in the country of Bucharia, where it occurs with sulphur in rocks of indurated clay. The ancients according to Pliny, called this salt *ammoniac*, because it was found near the temple of Jupiter Ammon, in Africa.

Hydriodate of ammonia. 294. *Hydriodate of Ammonia.*—In a former paragraph (283) the action of iodine on ammonia has been stated to produce a portion of hydriodate of ammonia: this compound may be directly formed by mixing equal volumes of hydriodic and ammoniacal gases; or by saturating liquid hydriodic acid by carbonate of ammonia; it forms very soluble and deliquescent cubic crystals, volatile in close vessels without decomposition.—Gay-Lussac, *Annales de Chim.* xci.

Nitrate of ammonia. 295. *Ammonia and Nitric Acid—Nitrate of Ammonia.*—This salt may be procured by the direct union of ammonia with nitric acid; or more easily, by saturating dilute nitric acid with carbonate of ammonia. It Specific gravity. has been mentioned as the source of nitrous oxide, and when heated is entirely resolved into that gas and water. * It consists of one proportional of nitric acid = 54 + one proportional of ammonia = 17, and therefore the representative number of nitrate of ammonia is 71. Or it may be considered as containing two proportionals of nitrogen, three of hydrogen, and five of oxygen, as the following symbols show:

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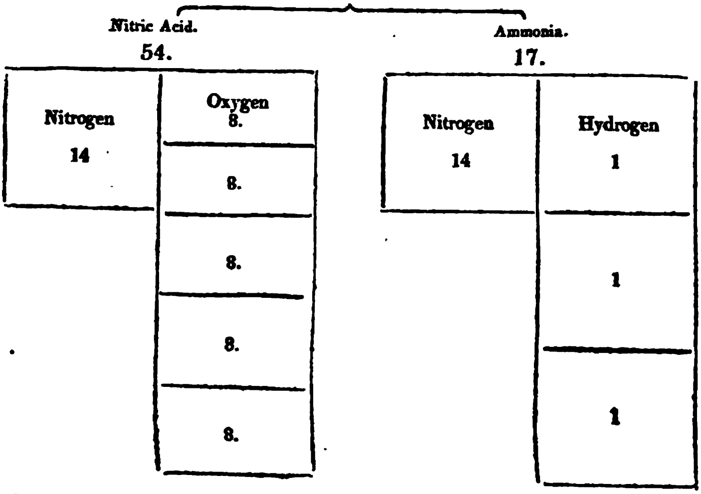
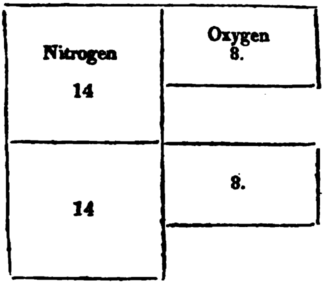
* Its specific gravity compared with water, is 1.5785. (Fourcroy).

Nitrate of Ammonia.

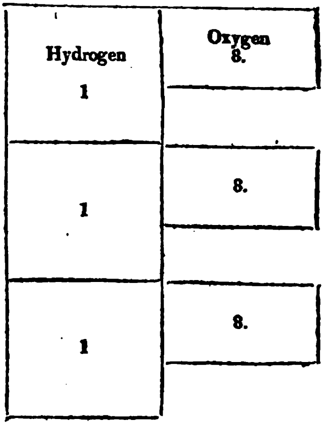


Nitrous oxide consists of 1 proportional of nitrogen = 14 + 1 of oxygen = 8; hence the 2 proportionals of nitrogen in the salt (1 in the acid and 1 in the ammonia,) will require 2 of oxygen to produce nitrous oxide, and the remaining 3 of oxygen will unite to the 3 of hydrogen, and form water; and accordingly nitrous oxide and water are the only possible results; so that the elements after the decomposition of the salt, are arranged thus:

Two proportionals of Nitrous Oxide.



Three proportionals of Water.



Proportions of water.

Nitrate of ammonia has long been known, and was formerly called *Nitrum flammans*. It differs in form according to the manner in which its solution has been evaporated; if at a temperature below 100°, its crystals are six-sided prisms terminated by six-sided pyramids; if boiled down, its crystals are thin and fibrous: it is deliquescent, and soluble in twice its weight of water at 60°, and in its own weight at 212°. Its taste is acrid and bitter. It contains different proportions of water of crystallization; according to Berzelius, the prismatic variety affords

11.232 *per cent.* (80 *Annales de Chimie.*) According to Davy, the fibrous variety contains 8.2 *per cent.;* and the compact, obtained by evaporating the solution till it concretes, 5.7 *per cent.* of water of crystallization.—DAVY's *Researches*, p. 71.

Atmospheric. air.

294. *Atmospheric Air.*—The composition of atmospheric air has been frequently alluded to in the preceding pages, and as the student is now acquainted with its essential component parts, namely, oxygen and nitrogen, it may be right to consider its properties more at length.

The atmosphere is a thin, transparent, invisible, and elastic fluid, which surrounds our planet and reaches to a considerable height above its surface, probably about 40 miles.

That air is a ponderous body, was first suspected by Galileo, who found that a copper ball, in which the air had been condensed, weighed heavier than when the air was in its ordinary state of tension. The fact was afterwards demonstrated by Torricelli, whose attention was drawn to the subject by the attempt of a well-digger at Florence, to raise water by a sucking-pump to a height exceeding 33 feet. It was then found that the pressure of the atmosphere, and not nature's abhorrence of a vacuum, was the cause of the ascent of the water in the pump-pipe, and that a column of about the height mentioned was sufficient to equipoise the atmosphere.

In 1643, Torricelli filled a glass tube, three feet long and closed at one end, with quicksilver, and inverted it in a basin of the same fluid; he found that the mercury fell about six inches, so that the atmosphere appeared capable of counterbalancing a column of mercury 30 inches in height. The empty space, in the upper part of the tube, has hence been called the *Torricellian vacuum*, and is the most perfect that can be formed.

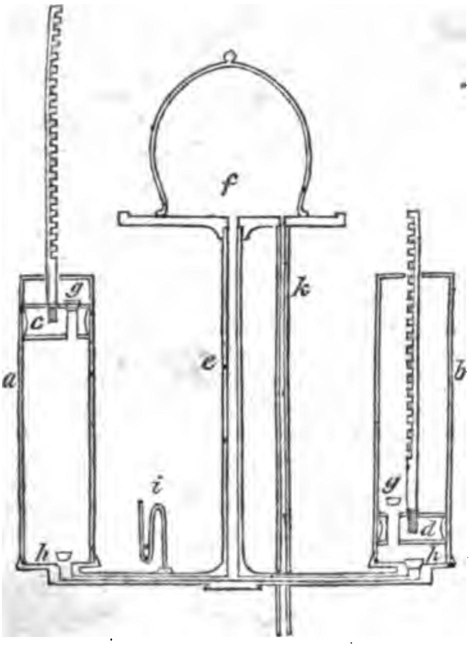
Paschal and Torricelli afterwards observed, that upon ascending a mountain, the quicksilver fell in the tube, because there was less air above to press upon the surface of the metal in the basin; and thus a method of measuring the heights of mountains by the *barometer*, as the instrument is now called, was devised. Sir Henry Englefield has constructed a barometer, expressly for these investigations, the mode of using which is described in the *Journal of Science and the Arts*, Vol. v. p. 229.

The barometer indicates, by its rise and fall, a corresponding change in the density of the atmosphere. At the surface of the earth the mean density or pressure is considered equal to the support of a column of quicksilver 30 inches high.

	Inches.
At 1000 feet above the surface the column falls to	28.91
2000	27.86
3000	26.85
4000	25.87
5000	24.93
1 Mile	24.67
2	20.29
3	16.68
4	13.72
5	11.28
10	4.24
15	1.60
20	0.95

Mechanical properties of air.

295. The general mechanical properties of the air are best illustrated by the *air-pump*, the construction of which much resembles that of the common sucking-pump used for raising water, excepting that all the parts are more accurately and nicely made, the object being to exhaust the air as completely and expeditiously as possible. The annexed sketch will give an idea of the operation of the common air-pump *a b* are cylinders, into which the sliding-pistons *c d* are accurately fitted. *e* is a tube issuing from the bell-glass placed upon a brass plate *f*, and entering the lower part of the cylinders at *h h*, where are valves opening upwards. In each piston is also a valve opening upwards at *g g*. The cylinder *a* represents the piston in the act of being drawn up. By elevating the piston *c* an attempt will be made to form a vacuum underneath it; but a portion of the air in consequence of its elasticity, will pass out of the bell *f*, along the tube *e*, and elevating the valve *h*, will fill the space below the piston, the valve *g* being kept closed by the weight of the incumbent atmosphere. In the cylinder *b* the piston is represented in the act of depression, the valve *h* therefore is forced down upon the orifice, which it perfectly closes; and the air, confined between it and the piston, now makes its escape by the piston-valve *g*, which is accordingly open, so that at every stroke of the pump a portion of air is withdrawn from the receiver *f*.



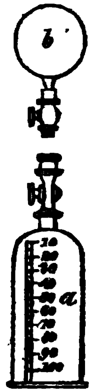
With this air-pump it is obviously impossible to obtain more than an imperfect vacuum in the receiver *f*, for the valves can only act by the elasticity of the remaining air; and, accordingly, if a barometer be placed under the receiver, the mercury will never attain a level in the tube and basin, but will always indicate a degree of pressure, as is shown by the small syphon gauge at *i*; and if a tube 3 feet long have its upper end opening into the receiver, and its lower end plunged into a bason of mercury, the mercury will never rise so high as in the common barometer, where the vacuum above it is perfect, but will indicate the pressure of a remnant of air in the receiver. The syphon gauge, and the barometer as applied at *k*, are very useful appendages to the air-pump, as showing the degree of exhaustion, and its permanence.

The operation of the pump in removing air, and the mechanical properties of the atmosphere, may be shown by a variety of experiments. Its pressure is illustrated by the force with which the bell-glass is pressed down upon the plate of the pump; the absence of its buoyancy, by the descent of a guinea and a feather at the same time in the exhausted receiver; and by the preponderance of the larger of two bodies which balance each other in the open air. The want of resistance in the exhausted receiver is also shown by the equal duration of the motion of two fly wheels, with their plates placed in different directions.

296. The specific gravity of atmospheric air, at mean temperature and pressure, that is, the thermometer being at 60°, and the barometer at 30 inches, is usually considered as = 1. It is about 828.59 times as light as its bulk of water, 100 cubical inches weighing 30.5 grains.

For ascertaining the specific gravity of gaseous bodies, a good air-pump is essentially requisite; a light glass balloon or flask *b*; and a graduated air-jar *a*, each supplied with stopcocks, are also required.

Dr. Henry, in his excellent *Elements of Chemistry*, (Vol. i. p. 126,) has given the following directions for proceeding to estimate the specific gravity of gases, which can scarcely be improved upon; it only requires to be observed, that the gases should, in general, be retained and collected over mercury, and carefully dried by exposing them to proper substances for absorbing the moisture which they hold in solution, and which would materially affect the accuracy of the result; or they should be taken saturated with moisture, and a deduction afterwards made for the weight of the vapour contained in a given bulk of the gas.



Supposing the receiver *a* to be filled with any gas, the weight of which is to be ascertained, we screw the cock of the vessel *b* on the plate of an air-pump, and exhaust it as completely as possible. The weight of the exhausted vessel is then very accurately taken, even to a small fraction of a grain; and it is screwed upon the air-cock of the receiver *a*. On opening both cocks, the last of which should be turned very gradually, the gas ascends from the vessel *a*; and the quantity which enters into the flask, is known by the graduated scale on *a*. On weighing the vessel a second time, we ascertain how many grains have been admitted. If we have operated on common air, we shall find its weight to be at the rate of 30.5 grains to 100 cubical inches. The same quantity of oxygen gas will weigh 33.75 grains, and of carbonic acid gas 46.57 grains.

In experiments of this kind it is necessary either to operate with the barometer at 30 inches, and the thermometer at 60° Fahrenheit, or to reduce the volume of gas employed to that pressure and temperature, by rules which are given in the note*. Great care is to be taken, also, not to warm any of the vessels by contact with the hands, from which they should be defended by a glove. On opening the communication between the receiver and the exhausted vessel, if any water be lodged in the air-cock attached to the former, it will be forcibly driven into the latter, and the experiment will be frustrated. This may be avoided by using great care in filling the receiver with water, before passing into it the gas under examination.

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* *Rules for reducing the Volume of Gases to a mean Height of the Barometer, and mean Temperature.*

i. *From the space occupied by any quantity of gas under an observed degree of pressure, to infer what its volume would be under the mean height of the barometer, taking this at 30 inches, as is now most usual.*

This is done by the rule of proportion; for, as the mean height is to the observed height, so is the observed volume to the volume required. For example, if we wish to know what space would be filled, under a pressure of 30 inches of mercury, by a quantity of gas, which fills 100 inches, when the barometer is at 29 inches.

30 : 29 : : 100 : 96.66.

The 100 inches would, therefore, be reduced to 96.66.

ii. *To estimate what would be the volume of a portion of gas, if brought to the temperature of 60° Fahrenheit.*

Divide the whole quantity of gas by 480; the quotient will show the amount of its expansion or contraction by each degree of Fahrenheit's thermometer. Multiply this by the number of degrees, which the gas exceeds, or falls below 60°. If the temperature of the gas be above 60°, subtract, or if below 60°, add, the product to the absolute quantity of gas; and the remainder in the first case, or sum in the second, will be the answer. Thus, to find what space 100 cubic inches of gas at 50° would occupy if raised to 60°, divide 100 by 480; the quotient 0.208 multiplied by 10 gives 2.08, which added to 100 gives 102.08, the answer required. If the temperature had been 70°, and we had wished to know the volume which the gas would have occupied at 60°, the same number 2.08 must have been subtracted from 100, and 97.92 would have been the answer.

iii. In some cases, it is necessary to make a double correction, or *to bring the gas to a mean both of the barometer and thermometer*. We must then first correct the temperature, and afterwards the pressure. Thus, to know what space 100 inches of gas at 70° Fahrenheit, and 29 inches barometer, would fill at 60° Fahrenheit and 30 inches barometer, we first reduce the 100 inches, by the second process, to 97.92. Then by the first,

30 : 29 : : 97.92 : 94.63.

Or 100 inches thus corrected, would be only 94.63.

iv. *To ascertain what would be the absolute weight of a given volume of gas at a mean temperature, from the known weight of an equal volume at any other temperature:* first, find by the second process what would be its bulk at a mean temperature; and then say, as the corrected bulk is to the actual weight, so is the observed bulk to the number required. Thus, if we have 100 cubic inches of gas weighing 50 grains at 50° Fahrenheit, if the temperature were raised to 60° they would expand to 102.08. And

102.08 : 50 : : 100 : 49.

Therefore 100 inches of the same gas at 60° would weigh 49 grains.

v. *To learn the absolute weight of a given volume of gas under a mean pressure, from its known weight under an observed pressure*, say as the observed pressure is to the mean pressure, so is the observed weight to the corrected weight. For example, having 100 inches of gas which weigh 50 grains under a pressure of 29 inches, to know what 100 inches of the same gas would weigh, the barometer being 30 inches,

29 : 30 : : 50 : 51.72.

Then 100 inches of the same gas, under 30 inches' pressure, would weigh 51.72 grains.

vi. In some cases it is necessary to combine the two last calculations. Thus, if 100 inches of gas at 50° Fahrenheit, and under 29 inches' pressure, weigh 50 grains, to find what would be the weight of 100 inches at 60° Fahrenheit, and under 30 inches of the barometer, first correct the temperature, which reduces the weight to 49 grains. Then,

29 : 30 : : 49 : 50.7.

100 inches, therefore, would weigh 50.7 grains.

The specific gravity of any gas compared with common air is readily known, when we have once determined its absolute weight. Thus, if 100 cubic inches of air weigh 30.5 grains, and the same quantity of oxygen gas weigh 33.88 grains, we say,

30. 5 : 33.88 : : 1.000 : 1.1111.

The specific gravity of oxygen gas, compared with atmospheric air, will, therefore, be as 1.1111 to 1.000.

We may determine, also, the specific gravity of gases more simply by weighing the flask, first when full of common air, and again when exhausted; and afterwards by admitting into it as much of the gas under examination as it will receive, and weighing it a third time. Now as the loss between the first and second weighing is to the gain of weight on admitting the gas, so is common air to the gas whose specific gravity we are estimating. Supposing, for example, that by exhausting the flask it loses 30.19 grains, and that by admitting carbonic acid it gains 46.57; then

30.5 : 46.57 : : 1.000 : 1.527.

The specific gravity of carbonic acid is therefore 1.527, air being taken at 1.000. And knowing its specific gravity, we can, without any farther experiment, determine the weight of 100 cubic inches of carbonic acid; for, as the specific gravity of air is to that of carbonic acid, so is 30.5 to the number required; or

1.000 : 1.527 : : 30 5 : 46.57.

100 cubic inches, therefore, of carbonic acid will weigh 46.57 grains.

Assuming atmospheric air at 30 inches barometrical pressure, and 60° temperature = 1, the following Table exhibits a series of comparative specific gravities; the First column shows the results of experiments chiefly made at the Royal Institution: The Second contains the weight of 100 cubic inches, calculated from the preceding column: the Third, specific gravities upon other authorities; and the Fourth contains some calculated results obtained by M. Gay-Lussac; and others.

GAS.	Specific Grav.	100 Cub. In.	Other Authorities.	OBSERVATIONS.
		grs.		
Atmospheric air	1.0000	30.20		The average weight of 100 cubic inches of atmospheric air, deduced from twelve experiments made with great care and an excellent balance, is 30.199 grains, at mean temperature and pressure. Sir G. Shuckburgh's experiments give the weight of 100 cubic inches = 30.5, and the table given by Dr. Thomson (System iii. 25,) is founded on this *datum*.
Oxygen	1.1175	33.75	1.10359 Biot and Arago	
Chlorine	2.4957	75.37	2.470 Gay-Lussac and Thenard 2.500 Prout	
Oxide of Chlorine	2.3653	71.43	2.361 Thomson	
Iodine (vapour of)	8.7723	264.90	8.678 Gay-Lussac	
Hydrogen	0.0745	2.25	0.07321 Biot and Arago	
Water (vapour of)	0.6235	18.80	0.624 Gay-Lussac	
Muriatic acid	1.2851	38.80	1.278 Biot and Gay-Lussac	
Hydriodic acid	4.4234	133.60	4.375 Thomson	
Nitrogen	0.9681	29.25	0.96913 Biot and Arago	
Nitrous oxide	1.5272	46.12	1.36293 Berthollet	1.52092. Upon the supposition that its elements suffer a condensation equal to the volume of its oxygen.
Nitric oxide	1.0428	31.50	1.0388 Berard	The mean of equal volumes of oxygen and nitrogen.
Nitrous acid	2.1356	64.50	2.1099 Gay-Lussac	
Ammonia	0.5969	18.00	0.5966 Biot and Arago	0.59439. Supposing the condensation of elements = 0.5 of their entire volume.
Sulphurous acid	2.2350	67.50	2.2553 Gay-Lussac & Thenard	
Sulphuretted hydrogen . . .	1.1920	36.00	1.1912 Ditto	
Phosphuretted hydrogen . . .	0.8940	27.00	0.9022 Thomson	
Hydrophosphoric gas	0.9685	29.25	0.9716 Ditto	
Carbonic oxide	0.9834	29.70	0.9569 Cruickshanks	0.96782. Supposing 100 of carbonic acid *minus* 50 oxygen to produce 100 carbonic oxide.
Chlorocarbonic acid	3.4791	105.07	3.472 Thomson	
Carbonic acid	1.5421	46.57	1.5196 Biot and Arago	
Carburetted hydrogen (olefiant)	0.9983	30.15	1.000 T. de Saussure	
Cyanogen	1.8178	54.90	1.804 Gay-Lussac	
Chlorocyanic acid	2.1527	65.13	2.152 Thomson	
Hydrocyanic acid	0.9461	28.57	0.9368 Ditto	
Sulphuret of Carbon (vapour of)	. . .	. . .	2.670 Gay-Lussac	
Fluoboric gas	2.400	72.50	2.3709 Thomson	
Fluosilicic gas	3.5740	110.78		
Alcohol (vapour of)	. . .	. . .	1.500 Gay-Lussac	
Sulphuric ether (ditto)	. . .	. . .	2.396 Ditto	
Muriatic ether (ditto)	. . .	. . .	2.219 Thenard	
Hydriodic ether (ditto)	. . .	. . .	5.475 Thomson	
Chloric ether (ditto)	. . .	. . .	3.474 Ditto	
Oil of turpentine (ditto) . . .	. . .	. . .	5.013 Ditto	

The chief numbers in this table were determined in the Royal Institution, the results therefore, cannot here be altered as they are of a peculiar nature, but elsewhere it has been done whenever no authority is given.

Composition of atmospheric air.

297. Atmospheric air has already been stated to consist essentially of oxygen and nitrogen gases; but whether it should be considered a mere mixture or a chemical compound seems a question not easily decided.

There are various ways of learning the proportion which the oxygen bears to the nitrogen; and as the relative fitness of the air for breathing has sometimes been considered as depending upon the quantity of oxygen contained in a given volume, the instruments used in these experiments have been called *eudiometers*.

298. From facts already stated it is obvious, that if atmospheric air, mixed with a certain quantity of hydrogen, be detonated by the electric spark (236 iii.) the absorption will be proportionate to the quantity of oxygen present.

When 100 measures of pure hydrogen are mixed with 100 of pure oxygen, the diminution of bulk after detonation will amount to 150 parts, that is, one volume of oxygen requires for its saturation two of hydrogen. If we introduce into the graduated detonating tube (p. 80) 300 measures of common air, and 200 of pure hydrogen, there will remain, after detonation 305 measures; so that 195 measures will have disappeared, of which one-third may be estimated as pure oxygen; hence 300 parts of air have thus lost 65 of oxygen, or about 21 *per cent.*

The general rule, therefore, for estimating the purity of air by hydrogen gas may be stated as follows:—Add to 3 measures of the air under examination 2 measures of pure hydrogen; detonate; and, when the vessel has cooled, observe the absorption; divide its amount by 3, and the quotient is the quantity of oxygen.

Upon the same principle, detonation of mixtures of oxygen and hydrogen is often resorted to, with a view of ascertaining the purity of those gases. Thus, suppose 100 measures of oxygen, and 300 of hydrogen, to be reduced by detonation to 130, the whole diminution will be =270, which, divided by 3, gives 90 for the quantity of oxygen; so that it contained 10 *per cent.* of some gas, not condensible by detonation with hydrogen.

To ascertain the purity of hydrogen, it may be detonated with excess of pure oxygen. Thus, if we add 100 of pure oxygen to 100 of hydrogen, and detonate, there will be a diminution equal to two-thirds, or 150 parts if the hydrogen be pure. If, however, we suppose 100 of pure oxygen, mixed with 100 of hydrogen, to produce, after detonation, a residue of 80 measures; the diminution will then have been only 120 measures, of which two-thirds, or 80 measures, are hydrogen; so that the inflammable gas will have contained 20 *per cent.* of some other gaseous body, not condensible by detonation with hydrogen.

Eudiometer of Volta.

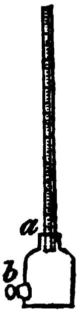
This mode of ascertaining the purity of atmospheric air was first resorted to by Volta, and it is susceptible of great accuracy, since pure hydrogen and pure oxygen are easily procured. An improved detonating tube for these purposes has been described by M. Gay-Lussac, *Annales de Chim. et Phys.* IV. 188.

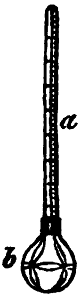
Of Scheele.

300. Scheele, in his eudiometrical experiments, employed *sulphuret of potassa*, (556) the solution of which rapidly absorbs oxygen, as may be shown by agitating it with some atmospheric air in a graduated glass tube. In this experiment the nitrogen remains unaltered.

Of Hope.

The best instruments for these experiments are the eudiometric tubes of Dr. Hope (NICHOLSON's *Journal*, Vol. iv.) and Dr. Henry (*Elements*, Vol. i. p. 149) as represented in the marginal woodcuts. The former consists of a small bottle, holding about three ounces, into which the graduated glass tube *a* is carefully fitted by grinding. It also has a ground stopper at *b*. To use it, the phial is filled with the solution of the alcaline sulphuret, and the tube *a*, containing the air to be examined, fitted into its place. After inverting and agitating the instrument, the stopper *b* may be opened under water, and the absorption is shown by the rise of the fluid in the tube. For the glass bottle Dr. Henry substituted the elastic gum bottle *b*, in the neck of which a short piece of glass tube is secured, into which the tube *a* is fitted by grinding.





Of Pepys.

In the *Philosophical Transactions* for 1807, Mr. Pepys has described a modification of this Eudiometer, which may be often advantageously employed in delicate experiments, and by which an absorption of only $\frac{1}{1000}$ part of the gas under examination may be measured.

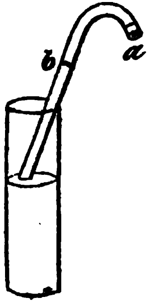
Of Priestley.

301. When nitric oxide gas and atmospheric air are mixed, there is a production of nitrous acid, in consequence of the union of oxygen with the oxide (273); and if the mixture be made over water, an absorption proportional to the quantity of nitrous acid formed ensues. Upon this principle nitric oxide may be used in eudiometrical experiments, and, if proper precautions be attended to, it furnishes tolerably accurate results. Dr. Priestley and Mr. Cavendish (*Phil. Trans.* 1783,) availed themselves of this mode, and Mr. Dalton has offered some remarks upon its relative accuracy (*Phil. Mag.* Vol. xxviii.) The most certain results are obtained by adding to 100 parts of the atmospheric air, previously introduced into a small beer glass, an equal volume of nitric oxide gas. The mixture may be gently agitated, and in two or three minutes, carefully decanted into a graduated tube, when it will be found that 84 measures have disappeared; of which one-fourth, or 21 measures, are oxygen.

Of Davy.

Sir H. Davy suggested the use of a solution of sulphate of iron, impregnated with nitric oxide gas, for the absorption of oxygen; it may be employed in the same way as the alcaline sulphuret (300.)

302. If a stick of phosphorus be confined in a portion of atmospheric air it will slowly absorb the oxygen present. The rapid combustion of the same substance may also be conveniently resorted to. For this purpose a small piece of phosphorus may be introduced into the bulb of the tube *a*, containing a given measure of the air to be examined, confined over mercury, which, to prevent loss by expansion, should be suffered to occupy about half the tube, or to stand at *b*. The phosphorus may then be inflamed in the tube; and when the combustion is over, and the tube cold, the residuary air may be transferred for measurement. These eudiometrical methods were used by Lavoisier, Berthollet, and Seguin



Of Lavoisier, &c.

(*Annales de Chimie*, tom ix. and xxxiv.) and are both susceptible of accuracy, and a loss of volume = 21 *per cent.* of the atmospheric air, will invariably be found to have occurred.

303. By experiments thus conducted, it has been found that the composition of the atmosphere is extremely uniform in all parts of the world, and at all heights above its surface; and that it consists of,

	By Measure.	By Weight.
Oxygen	21	23.3
Nitrogen	79	76.7
	100	100.0

Though these are the essential component parts of atmospheric air, it contains other substances, which, however, may be regarded as adventitious, and the quantity of which is liable to vary: of these, carbonic acid and aqueous vapour are the most important and constant. The quantity of the former may usually be considered as amounting to less than 1 *per cent.*

Carbonic acid in air.

The presence of aqueous vapour in the atmosphere is shown in a variety of ways, but most easily by exposing to it certain deliquescent substances which liquefy and increase in weight, in consequence of its absorption; and as the gases in general, unless artificially dried, also contain vapour of water, it is necessary, in delicate experiments, and in ascertaining their specific gravity, to take this ingredient into the account, or to separate it by proper means, such as exposure to very deliquescent substances, among which fused chloride of calcium (623) is especially useful.

Water in air.

The quantity of water contained in air and gases is subject to variation. From the experiments of Saussure and Dalton, it appears that 100 cubic inches of atmospheric air at 57°, are capable of retaining 0.35 grains of watery vapour; in this state the air may be considered at its maximum of humidity: it would also appear that all the gases take up the same quantity of water when under similar circumstances, and that it consequently depends, not upon the density or composition, but upon the bulk of the gaseous fluid.

We are indebted to Mr. Dalton for some valuable information respecting the state in which water exists in air; from which it may be concluded that it is in the state of vapour, forming an independent atmosphere, mixed, but not combined with, or dissolved in the air.

304. *Hygroscopes* and *Hygrometers* are instruments which show the presence of water in the air, its variation in quantity, and its actual quantity existing in a given bulk of air at any given time. Saussure employs a human hair, which, by its dilitations and contractions in moisture and dryness, is made to turn an index; Deluc used a thin strip of whalebone in the same way; Wilson employs a rat's bladder, which is filled with mercury, and tied on to a large thermometer tube, and by its dilatation and contraction causes the mercury to fall and rise in the tube, and thus to indicate changes in the moisture of the air. Mr. Daniell has constructed an hygrometer, which shows the constituent temperature of the moisture in the atmosphere, by its precipitation upon a cold surface; comparing this with the temperature of the atmosphere, the difference furnishes a datum for calculating the quantity of vapour in a given quantity of air, and affords indications usefully applicable to

Hygrometer.

predicting change of weather. A detailed account of this instrument, and of the observations made with it, is given by Mr. Daniell in the *Quarterly Journal of Science*, Vols. viii. ix. and x.

SECTION III. *Sulphur.*

305. SULPHUR, or brimstone, is a brittle substance, of a pale yellow colour, insipid and inodorous, but exhaling a peculiar smell when heated. Its specific gravity is 1.990[*]. It becomes negatively electrical by heat and by friction. Properties.

Sulphur is principally a mineral product, and occurs crystallized, its primitive form being a very acute octoëdron with an oblique base. Its crystals are in a high degree doubly refractive.

306. When sulphur is heated to about 180°, it volatilizes, and its peculiar odour is strong and disagreeable; at 225° it liquefies; between 350° and 400° it becomes viscid, and of a deep brown colour; and at about 600° it quickly sublimes. When slowly cooled after fusion, it forms a fibrous crystalline mass. It suffers no change by exposure to air, and is insoluble in water. It is met with in masses, in rolls or sticks, and in the form of powder, when it is usually called *flowers of sulphur*, or *sublimed sulphur*. Action of heat, Flowers of sulphur.

307. Sublimed sulphur, when examined by a microscope appears composed of minute crystals; it is always slightly sour, and hence, for some pharmaceutical purposes, is directed to be washed with hot water. Crystallizes.

308. Massive sulphur is chiefly brought to this country from Sicily; it occurs native, and is found associated with sulphate of lime, sulphate of strontia, and carbonate of lime. Its colour is various shades of yellow, and the transparent crystals are doubly refractive; it is not uncommon among volcanic products. How obtained.

309. Roll-sulphur is chiefly obtained from sulphuret of copper in this country; which is roasted, and the fumes received into a long chamber of brick-work, where the sulphur is gradually deposited: it is then purified by fusion, and cast into sticks. In this state, if grasped by the warm hand, it splits with a crackling noise.

310. For some pharmaceutical purposes sulphur is precipitated from its alcaline solutions, as from sulphuret of potassa (556) by an acid, and, when washed and dried, is in the form of a yellowish-grey impalpable powder; it is the *milk of sulphur* and *precipitated sulphur* of the *Pharmacopœia*. Dr. Thomson considers it as a compound of sulphur and water.—*System of Chem*. Vol. i. 285.

311. The purity of sulphur may be judged of by heating it gradually upon a piece of platinum leaf; if free from earthy impurities, it should totally evaporate. It should also be perfectly soluble in boiling oil of turpentine.—AIKIN's *Dictionary*, Art. SULPHUR.

312. *Sulphur and Oxygen.*—Sulphur forms two well-defined compounds with oxygen, the sulphurous and sulphuric acids; two other Unites with oxygen.

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[*] The sp. gr. of sulphur vapour compared with oxygen, is the same or equal to 1; now 1 × 2 = 2 the atom of sulphur, and 2 is just 16 times 0,125 (the atom of hydrogen.)

Sulphurous acid.

compounds of sulphur and oxygen have also been described under the names of *Hyposulphurous* and *Hyposulphuric Acids;* but these can scarcely be said to exist, except in combination with bases, and what is known respecting them will be found under the articles *Hyposulphite of Lime* (630) and *Hyposulphate of Baryta* (639). If they be admitted as distinct compounds, sulphur may be considered as susceptible of four states of combination with oxygen, and these compounds will consist respectively of

1 Sulphur + 1 Oxygen = Hyposulphurous acid.
1 Ditto + 2 Ditto = Sulphurous acid.
1 Ditto + 2.5 Ditto = Hyposulphuric acid.
1 Ditto + 3 = Sulphuric acid.

313. *Sulphurous acid* is a gaseous body, which may be obtained by several processes. It may be procured directly, by burning sulphur in oxygen gas; or indirectly, by boiling mercury in sulphuric acid. It must be collected and preserved over mercury; for water takes up rather more than 30 times its bulk of this gas, forming the liquid sulphurous acid, which, when recently prepared, has a sulphurous astringent taste, and destroys many vegetable colours; but, by keeping, it acquires a sour flavour, and reddens the generality of vegetable blues.

314. If sulphur be burned in oxygen, sulphurous acid is produced without any change in the volume of the gas, so that its composition is easily learned by the increase of weight; and as 100 cubic inches of oxygen (weighing 33.88 grains) dissolve 33.88 grains of sulphur, it is obvious that the sulphurous acid is composed of equal weights of sulphur and oxygen; and if we regard it as consisting of two proportionals of oxygen and one of sulphur, the latter element will be represented by the number 16; and the sulphurous acid, consisting of 1 proportional of sulphur = 16, and 2 of oxygen = 16, will be represented by 32, which is also its relative specific gravity to hydrogen, considering the latter as = 1*; 100 cubical inches of sulphurous acid gas weigh 67.75 grains. This gas has a suffocating nauseous odour, and an astringent taste; it extinguishes flame, and kills animals.

315. Sulphurous acid suffers no change at a red heat, but if mixed with hydrogen, and passed through a red hot tube, water is formed and sulphur deposited; under the same circumstances, it is also decomposed by charcoal, by potassium and sodium, and probably by several other metals. Prepared by the combustion of sulphur, it is much used for bleaching cotton goods (*Quarterly Journal of Science*, iv. 196,) and also for whitening silk and wool; in wine countries it is sometimes used to check vinous fermentation.

316 When sulphurous acid is mixed in equal volume with ammonia, a yellowish salt is produced, which is a *sulphite of ammonia*, and which consists of 32 sulphurous acid + 17 ammonia. When formed by saturating liquid ammonia with sulphurous acid, it crystallizes in four and six-sided prisms, soluble in their own weight of water and having an acrid taste. It is deliquescent, and becomes a *sulphate* by exposure to air.

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* When sp. gr. of oxygen =1, that of sulphurous acid=2 this multiplied by 2 gives 4 for the atom of this acid, also 4 is just 32 times the atom (0.125) of hydrogen.

317. *Sulphuric Acid.*— This body was formerly obtained by the distillation of green vitriol, and called *oil of vitriol.* It is now procured in this country by burning a mixture of about 8 parts of sulphur and 1 of nitre in close leaden chambers containing water, by which the fumes produced are absorbed, and by evaporation the acid is procured in a more concentrated state. This improved method of preparing sulphuric acid was invented by Dr. Roebuck, about the year 1746.—Parkes's *Chemical Essays*, Vol. ii.—*Prefatory History of Chemistry.* Vol. i. p. 36.

Sulphuric acid.

318. Sulphuric acid, as usually met with, is a limpid colourless fluid, having a specific gravity of 1.80; it boils at 620°, and freezes at 15°, contracting at the same time considerably in its dimensions. But the temperature at which the diluted acid congeals is singularly modified by the quantity of water which it contains. At the specific gravity of 1.78 it freezes at about 40°; but if the density be either increased or diminished, a greater cold is required for its congelation (Keir, *Irish Phil. Trans.* iv. 88.) Its boiling point diminishes with its dilution; acid of the specific gravity of 1.78, boils at 435°, and acid of the specific gravity of 1.650 boils at 350°.—Dalton's *Chem. Phil.* ii. 404.

It is acrid and caustic, and when diluted with water, produces a very sour liquid. It rapidly absorbs water from the atmosphere, and upon sudden mixture with water, condensation ensues, and much heat is evolved. Even a boiling temperature, when it is concentrated, does not prevent its taking up moisture from the air; hence it cannot be concentrated so well in an open as in a close vessel, on which account retorts of glass or platinum are used for the last stage of its concentration by the manufacturers.

It chars animal and vegetable substances, and is apt to acquire a brown tinge from any small particles of straw, resin, or other matters that may accidentally have fallen into it.

319. In sulphuric acid 1 proportional of sulphur = 16, is combined with 3 of oxygen = 24, and, consequently, *dry* sulphuric acid is correctly represented by 16 + 24 = 40; but it only exists in this state (like the nitric and chloric acids) when united with bases, and in its ordinary state contains water, and may, therefore, be called *hydrated sulphuric Acid.* It has been found by experiment, that 100 parts of sulphuric acid, specific gravity 1.85, contain 18.5 of water; consequently, it may be looked upon as composed of 1 sulphur + 3 oxygen + 1 water:

Or of 16 sulphur
24 oxygen
9 water
———
49 number for liquid sulphuric acid.

100 Parts of liquid sulphuric acid, of the specific gravity of 1.3530, contain 37.5 parts of dry sulphuric acid; or 46 of liquid acid, of the specific gravity 1.85.

320. The strength of sulphuric acid is best judged of by its saturating power, and by its specific gravity. Mr. Dalton (*New System of Chemical Philosophy*, Vol. ii. p. 404,) has published a Table, exhibiting the specific gravity and boiling point of the acid of various strengths.

Dr. Ure also has given several valuable tables relating to this subject, in his *Experiments to determine the Law of Progression, followed in the Density of Sulphuric Acid at different Degrees of Dilution* (*Quarterly Journal of Science and the Arts*, Vol. iv. p. 114.) An extremely useful table of this kind will also be found in Mr. Parkes's *Essays* above quoted (Vol. ii. p. 444.)

The following is Dr. Ure's Table :

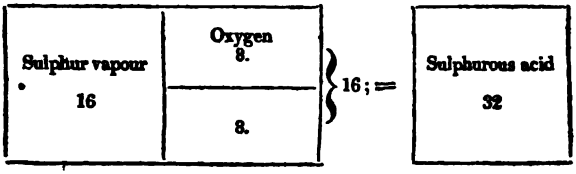
Liquid.	Sp. Gr.	Dry.	Liq.	Sp. Gr.	Dry.	Liq.	Sp. Gr.	Dry.
100	1.8485	81.54	66	1.5503	53.82	32	1.2334	26.09
99	1.8475	80.72	65	1.5390	53.00	31	1.2260	25.28
98	1.8460	79.90	64	1.5280	52.18	30	1.2184	24.46
97	1.8439	79.09	63	1.5170	51.37	29	1.2108	23.65
96	1.8410	78.28	62	1.5066	50.55	28	1.2032	22.83
95	1.8376	77.46	61	1.4960	49.74	27	1.1956	22.01
94	1.8336	76.65	60	1.4860	48.92	26	1.1876	21.20
93	1.8290	75.83	59	1.4760	48.11	25	1.1792	20.38
92	1.8233	75.02	58	1.4660	47.29	24	1.1706	19.57
91	1.8179	74.20	57	1.4560	46.48	23	1.1626	18.75
90	1.8115	73.39	56	1.4460	45.66	22	1.1549	17.94
89	1.8043	72.57	55	1.4360	44.85	21	1.1480	17.12
88	1.7962	71.75	54	1.4265	44.03	20	1.1410	16.31
87	1.7870	70.94	53	1.4170	43.22	19	1.1330	15.49
86	1.7774	70.12	52	1.4073	42.40	18	1.1246	14.68
85	1.7673	69.31	51	1.3977	41.58	17	1.1165	13.86
84	1.7570	68.49	50	1.3884	40.77	16	1.1090	13.05
83	1.7465	67.68	49	1.3788	39.95	15	1.1019	12.23
82	1.7360	66.86	48	1.3697	39.14	14	1.0953	11.41
81	1.7245	66.05	47	1.3612	38.32	13	1.0887	10.60
80	1.7100	65.23	46	1.3530	37.51	12	1.0809	9.78
79	1.6993	64.42	45	1.3440	36.69	11	1.0743	8.97
78	1.6870	63.60	44	1.3345	35.88	10	1.0682	8.15
77	1.6750	62.78	43	1.3255	35.06	9	1.0614	7.34
76	1.6630	61.97	42	1.3165	34.25	8	1.0544	6.52
75	1.6520	61.15	41	1.3080	33.43	7	1.0477	5.71
74	1.6415	60.34	40	1.2999	32.61	6	1.0405	4.89
73	1.6321	59.52	39	1.2913	31.80	5	1.0336	4.08
72	1.6204	58.71	38	1.2826	30.98	4	1.0268	3.26
71	1.6090	57.89	37	1.2740	30.17	3	1.0206	2.446
70	1.5975	57.08	36	1.2654	29.35	2	1.0140	1.63
69	1.5868	56.26	35	1.2572	28.54	1	1.0074	0.8154
68	1.5760	55.45	34	1.2490	27.72			
67	1.5648	54.63	33	1.2409	26.91			

Formation of sulphuric acid

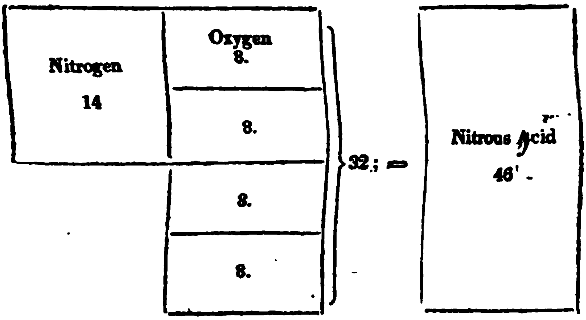
321. The *formation* of sulphuric acid by the combustion of sulphur and nitre is as follows :

The sulphur, by burning in contact with atmospheric, air forms *sulphurous acid.* The nitre gives rise to the production of *nitric oxide*, which, with the oxygen of the air, produces *nitrous acid gas.* When these gases (*i. e.*), sulphurous and nitrous acids) *are perfectly dry*, they do not act upon each other, but moisture being present in small quantity, they form a white solid, which is instantly decomposed when put into water; the nitrous acid reverts to the state of nitric oxide, having transferred one additional proportional of oxygen to the sulphurous acid, and, with water, producing the sulphuric acid; while the nitric oxide, by the action of the air, again affords nitrous acid, which plays the same part as before.

Sulphurous acid consists of

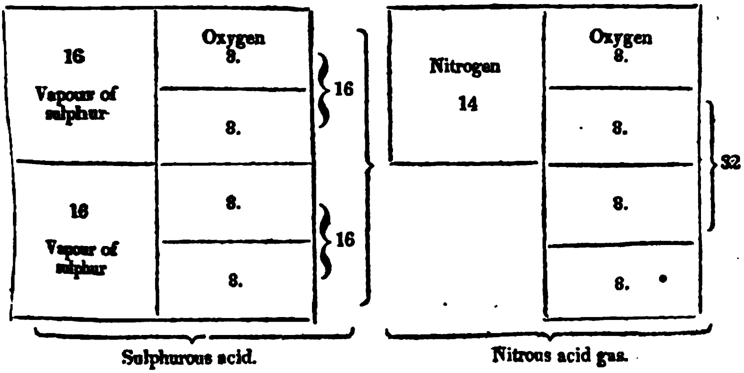


And nitrous acid contains

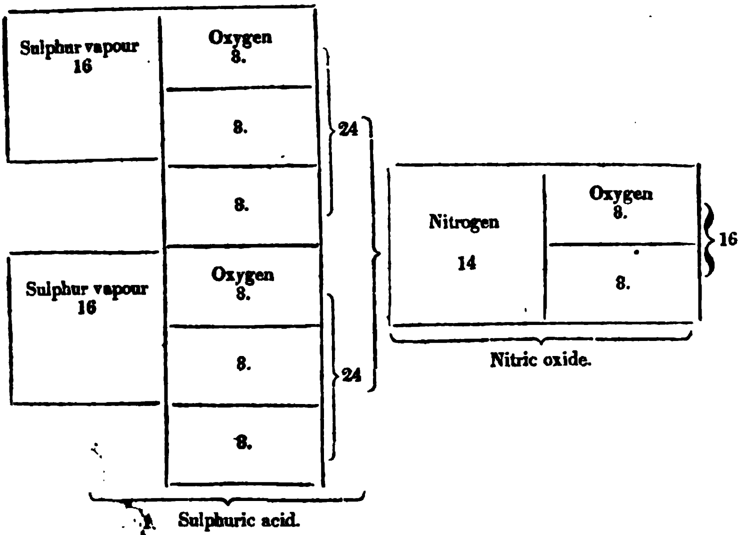


hence every *two* portions of sulphurous acid require *one* of nitrous acid, which transfers *two* of oxygen, and passes back into the state of nitric oxide, sulphuric acid being, at the same time, produced.

The gases, therefore, before decomposition, may be thus represented:



And after decomposition as follows:



Analysis of sulphuric acid. 322. The decomposition of sulphuric acid may be effected by passing it through a red-hot platinum tube, when it is resolved into sulphurous acid, oxygen, and water.

When heated with charcoal, sulphuric acid gives rise to the production of carbonic and sulphurous acids; with phosphorus it produces phosphoric and sulphurous acids; and, with sulphur, sulphurous acid is the only product. It is decomposed by several of the metals, which become oxidized, and evolve sulphurous acid, as shown in the production of this acid, by boiling sulphuric acid with mercury (313), tin, lead, *&c.*

Uses. 323. Sulphuric acid is largely consumed in a variety of manufactures. It is used by the makers of nitric, muriatic, citric, and tartaric acids; by bleachers, dyers, tin-plate makers, brass-founders and gilders. For these purposes it is generally sufficiently pure as it comes from the wholesale manufacturer; but, as traces of lead, lime, and potassa, are usually found in it, it often requires to be purified by distillation for the use of the experimental chemist.

The distillation of this acid in glass retorts requires some precaution, in consequence of the violent jerks which the production of its vapour occasions, and which often break the vessel; this may be prevented by putting some strips of platinum into the acid; it then boils quietly, and it is only necessary to take care that the neck of the retort and receiver are not broken in consequence of the high temperature of the condensing acid. This very useful contrivance to the practical chemist was first shown me by Mr. James South.

If the acid of commerce contain dissolved sulphate of lead, it becomes turbid on dilution, so that its remaining clear when mixed with water, is some proof of its purity, as far at least as lead is concerned.

324. When sulphuric acid was procured by the distillation of green vitriol, it was frequently observed that a portion concreted into a white

mass of radiated crystals. The same substance has also been remarked as occasionally formed in the acid of the English manufacturers. It has been called *glacial* or *fuming sulphuric acid*, and is by Dr. Thomson considered as the pure or anhydrous acid; it appears, however, probable, that it consists of sulphuric acid, combined with a portion of sulphurous acid.—See *Sulphate of Iron* (738.)

325. It has long been an object with the manufacturer to obtain sulphuric acid without the aid of nitre, and a patent has been obtained for a process of this kind, invented by Mr. Hill. It consists in submitting coarsely-powdered iron pyrites (737) (sulphuret of iron,) to a red heat, in cylinders communicating with a leaden chamber containing water; the sulphur, as it burns out of the pyrites, appears at once to pass into the state of sulphuric acid.

326. *Native Sulphuric Acid* has been found by Professor Baldassari, in the cavities of a small volcanic hill, called Zoccolino, near Sienna.

Iodo-sulphuric acid.

327. When sulphuric acid is dropped into a concentrated and hot solution of iodic acid, a peculiar compound is formed, which may be termed *iodo-sulphuric acid*; it is yellow, fusible, and crystallizes on cooling in rhomboids; at a higher temperature it partly sublimes, and is partly decomposed.

Sulphate of ammonia.

328. *Sulphuric Acid and Ammonia—Sulphate of Ammonia*—may be obtained by passing ammonia into sulphuric acid; but it is usually prepared by saturating dilute sulphuric acid with *carbonate of ammonia*, or by decomposing muriate of ammonia by sulphuric acid. It is the *secret sal-ammoniac* of some old writers. This salt is important as a source of the muriate of ammonia, (292) which is obtained by sublimation from a mixture of common salt and sulphate of ammonia; by this process sulphate of soda is also formed.

Sulphate of ammonia dissolves in twice its weight of water at 60°, and consists of 1 proportional of sulphuric acid =40 + 1 proportional of ammonia = 17. Its number, therefore, is 57. By crystallization it affords six-sided prisms. Its taste is bitter and pungent. When heated, it melts and in part sublimes, ammonia is given off, and a *supersulphate* remains, consisting of 2 proportionals of acid + 1 of alcali.

329. *Native Sulphate of Ammonia* is sometimes found in volcanic products; it occurs in stalactitic concretions of a whitish or yellowish colour, and covered with a white efflorescence: it has thus been procured from fissures in the earth surrounding certain small lakes in Tuscany, near Sienna; and among the products of Etna and Vesuvius; it has been termed by Karsten *Mascagnine*, from the name of its discoverer.

Chloride of sulphur.

330. *Sulphur and Chlorine—Chloride of Sulphur.* This compound was first described by Dr. Thomson, in 1804 (Nicholson's *Journal*, Vol. vii.) When sulphur is heated in chlorine, it absorbs rather more than twice its weight of that gas. 10 grains of sulphur absorb 30 cubic inches of chlorine, and produce a greenish-yellow liquid, consisting of 16 sulphur + 36.0 chlorine, and represented, therefore, by the number 52. It exhales suffocating and irritating fumes when exposed to the air. Its specific gravity is 1.6. It does not affect dry vegetable blues; but when water is present, it instantly reddens them, sulphur is deposited and sulphurous, sulphuric, and muriatic acids are

formed in consequence of a decomposition of the water. It dissolves sulphur and phosphorus.

Iodide of sulphur.

331. *Sulphur and Iodine* readily unite and form a black crystallizable compound, first described by M. Gay-Lussac.—*Annales de Chimie*, 91.

Sulphuretted hydrogen.

332. *Sulphur and Hydrogen—Sulphuretted Hydrogen gas—Hydrothionic acid.*—This gaseous compound of sulphur and hydrogen was discovered by Scheele in 1777. It may be obtained by presenting sulphur to nascent hydrogen, which is the case when sulphuret of iron is acted upon by dilute sulphuric acid. It may also be conveniently obtained by heating bruised sulphuret of antimony in muriatic acid.

333. Sulphuretted hydrogen gas may be collected over water, though, by agitation, that fluid absorbs nearly thrice its bulk. It has a peculiarly nauseous fetid odour, resembling that of rotten eggs. Its specific gravity* to hydrogen is as 17 to 1. 100 cubic inches weigh 36 grains. It is inflammable, and during its slow combustion, sulphur is deposited, and water and sulphurous acid formed. It extinguishes flame. When respired, it proves fatal; and it is very deleterious, even though largely diluted with atmospheric air. It exists in some mineral waters.

334. The aqueous solution of sulphuretted hydrogen is transparent and colourless, but if exposed to air it deposits sulphur and the gas escapes. It is an exceedingly delicate test of the presence of most of the metals, with which it forms coloured precipitates. It reddens infusion of litmus; and as it combines with the greater number of salifiable bases, it has by some been regarded as an acid. Gay-Lussac has termed it *hydrosulphuric acid.*

335. When one volume of sulphuretted hydrogen, and 1.5 of oxygen are inflamed in a detonating tube, 1 volume of sulphurous acid is produced, and water is formed. Thus the sulphur is transferred to 1 volume of the oxygen, and the hydrogen to the half volume. Sulphuretted hydrogen, therefore, consists of 16 sulphur + 1 hydrogen, and its number is 17. Sulphuretted hydrogen may also be decomposed by the Voltaic flame, in the apparatus shown at page 80, or by a succession of electric sparks. Its volume is unchanged, but the sulphur is thrown down.

336. Chlorine and iodine instantly decompose sulphuretted hydrogen; sulphur is deposited, and muriatic (248) and hydriodic (259) acids are formed. It is also decomposed by the metal potassium, which absorbs the sulphur and liberates pure hydrogen, when heated in the gas. Nitric acid poured into the gas occasions a deposition of sulphur, and nitrous acid and water are formed.

337. When sulphuretted hydrogen is mixed with its volume of nitric oxide over mercury, a diminution of bulk ensues, in consequence of the production of water; sulphur is deposited and nitrous oxide remains in the vessel.

338. When two volumes of sulphuretted hydrogen are mixed in an exhausted balloon with one of sulphurous acid, they mutually decompose each other, occasioning the production of water, and the deposition of sulphur; if the gases be perfectly dry, the action is slow.

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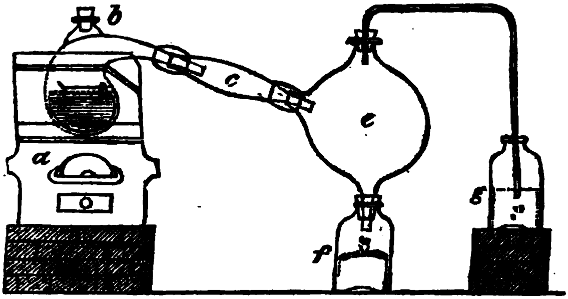
* When the specific gravity of oxygen = 1; that of sulph. hydrogen = 1.0625, now twice this or 2.125 is the atom, and 2.125 is just 17 times 0.125 (the atom of hydrogen.)

Hydrosulphuret of ammonia.

339. *Sulphuretted hydrogen and ammonia* readily unite in equal volumes, and produce *hydrosulphuret of ammonia.* At first white fumes appear, which become yellow, and a yellow crystallized compound results, consisting of 17 sulphuretted hydrogen, + 17 ammonia. It is of much use as a test for the metals, and may be procured by distilling at nearly a red heat, a mixture of 6 parts of slacked lime, 2 of muriate of ammonia, and 1 of sulphur.

340. The following is the disposition of the apparatus for this experiment: *a*, a small furnace: *b*, a tubulated earthen retort containing the above materials; *c*, an adapting tube; *e*, a glass balloon for condensing the vapour; *f*, a receiver; *g*, a bottle of water, into which the glass tube, issuing from the upper part of the receiver, *e*, is made to dip about half an inch.



The product in the bottle *f* may be mixed with the water in *g*, and the whole used for washing out the receiver *e*. In its concentrated state, this compound exhales white fumes, as was first remarked by Boyle, whence it was termed *Boyle's Fuming Liquor*, or *Volatile Liver of Sulphur*. It is a deep yellow liquid, smelling like a mixture of sulphuretted hydrogen and ammonia.

When kept in common white glass vessels it renders them brown or black, in consequence of its action on the oxide of lead which the glass contains.

341. Another compound of hydrogen and sulphur which has been called *supersulphuretted hydrogen*, is described in most books as a liquid formed by adding muriatic acid to a solution of sulphuret of potassa, and it is said to consist of two proportionals of sulphur = 32 + 1 of hydrogen = 1. I have, however, never been able to obtain it.

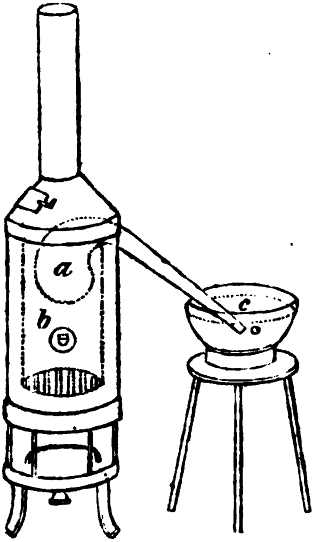
342. *Sulphur and Nitrogen* do not form any definite compound, though the nitrogen evolved during the decomposition of certain animal substances, often seems to contain sulphur.

343. Sulphur, in its ordinary state, always contains hydrogen, which it gives off during the action of various bodies for which it has a powerful attraction. Thus, if equal weights of sulphur and copper or iron-filings be introduced into a retort, and heated, a quantity of hydrogen, mixed with sulphuretted hydrogen, is evolved at the period of their combination.

SECTION IV. *Phosphorus.*

Method of preparing.

344. PHOSPHORUS is obtained by distilling concrete phosphoric acid with half its weight of charcoal at a red heat. This mixture is put into the coated earthen retort *a*, placed in the small portable furnace *b*; the tube of the retort should be immersed about half an inch into the basin of water *c*. A great quantity of gas escapes, some of which is spontaneously inflammable, and when the retort has obtained a bright red heat, a substance looking like wax, of a reddish colour, passes over: this, which is impure phosphorus may be rendered pure by melting it under warm water, and squeezing it through a piece of fine shamoy leather: but great care must be taken that none adheres to the nails or fingers, which would inflame on taking them out of the water, and produce a painful and troublesome burn. It is usually formed into sticks, by pouring it, when fluid, into a funnel tube under water.



345. In performing this distillation, a high temperature is required, so that the furnace should be sufficiently capacious to hold a body of charcoal piled up above the retort, which as earthenware becomes permeable to the vapour of phosphorus at a red heat, must be coated with a mixture of slaked lime and solution of borax; this mixture may be laid on with a brush, in two or three successive coats, and forms an excellent *vitrifiable lute.*

346. When pure, phosphorus is nearly colourless, semitransparent, and flexible. *Its specific gravity is 1.770. It melts, when air is excluded, at 105°. If suddenly cooled after having been heated to 140°,

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* The specific gr. *of phosphorus vapour* compared with oxygen, as the standard is 0.75; now this multiplied by 2 gives 1.5 for the atom of phosphorus, and 1.5 is just 12 times 0.125 (atom of hydrogen.)

it becomes black; but if slowly cooled, remains colourless. At 550° it boils, air being excluded, and rapidly evaporates. When exposed to air, it exhales luminous fumes, having a peculiar alliaceous odour; it is tasteless, and insoluble in water, but proves poisonous when taken into the stomach (ORFILA, *Traité des Poisons*, II., P. ii., p. 186.) In pure nitrogen, phosphorus is not in the least luminous at any temperature.

347. At a temperature of about 100° phosphorus takes fire, and burns with intense brilliancy, throwing off copious white fumes. If, instead of burning phosphorus with free access of air, it be heated in a confined portion of very rare air, it enters into less perfect combustion, and three compounds of phosphorus with oxygen are the result, each characterized by distinct properties. The first is a red solid, less fusible than phosphorus; the second is a white substance, more volatile than phosphorus; the third, a white and more fixed body.

348. The red solid consists of a mixture of phosphorus and oxide of phosphorus. *Oxide of Phosphorus* is the white substance with which phosphorus becomes incrusted when kept for some time in water. It is very inflammable, and less fusible and volatile than phosphorus. It is this substance which is generally used in the *phosphoric match-boxes*. To prepare it for this purpose, a piece of phosphorus may be put into a small phial, and melted and stirred about with a hot iron wire so as to coat its interior. A portion of the phosphorus is thus oxidized by its imperfect combustion, and a small quantity taken out upon the end of a brimstone match, instantly inflames upon coming into the contact of the air.

Union with oxygen.

349. *Phosphorus and Oxygen.*—Besides the oxide of phosphorus, which has just been alluded to, there are three *acid* compounds of phosphorus and oxygen, which have been termed *hypophosphorous*, *phosphorous*, and *phosphoric* acids.

350. *Hypophosphorous Acid* was discovered by M. Dulong, (*Annales de Chimie et Physique*, Vol. ii. p. 141). It is prepared as follows: Upon 1 part of *phosphuret of barium* (643) pour 4 parts of water, and when the evolution of phosphuretted hydrogen gas has ceased, pour the whole upon a filter. To the filtered liquid add sulphuric acid as long as any precipitate forms; separate the precipitate, which is a compound of sulphuric acid and baryta, and the clear liquor now contains the hypophosphorous acid in solution.

When concentrated by evaporation, a sour viscid liquid is obtained, incapable of crystallization, and eagerly attractive of oxygen.

351. *Phosphorous Acid* was first examined in its pure state, by Sir H. Davy. It is best obtained by mixing *chloride of phosphorus* (364) with water and filtering and evaporating the solution, when a white crystallized solid is obtained, of a sour taste and very soluble. This body consists of phosphorous acid combined with water, and has, therefore, been called *hydro-phosphorous acid*.

352. *Phosphoric Acid* may be formed by burning phosphorus in excess of oxygen. There is intense heat and light produced, and white deliquescent flocculi line the interior of the receiver. It is produced in the same way by burning phosphorus under a dry bell-glass in atmospheric air. Phosphoric acid may also be obtained by acting upon phosphorus by nitric acid: in this case, if the action be at all intense, a portion of ammonia is at the same time produced, which is found in the state of phosphate of ammonia in solution. About six parts of nitric

acid, specific gravity 1.4, are introduced into a tubulated retort placed in a sand heat, with a tubulated receiver luted on to it, the stopper of which should be open. When the acid is warm, drop into it gradually one part of phosphorus in small pieces ; red nitrous vapour is instantly disengaged, and when its evolution ceases, put the stopper loosely into the receiver, and distil till the residue in the retort acquires the consistence of syrup ; pour it into a platinum crucible, and give it a dull red heat : it is pure phosphoric acid.

353. The exposure of *phosphate of ammonia* (360) to a red heat in a platinum crucible, also affords very pure phosphoric acid.

Method of procuring.

354. For the purpose of procuring phosphorus, phosphoric acid is most economically obtained by the decomposition of *bone earth*, which consists chiefly of phosphate of lime. The following is the mode of proceeding :

On 20 pounds of calcined bone, finely powdered, pour 20 quarts of water, and 8 pounds of sulphuric acid, diluted with an equal weight of water. Let these materials be stirred together, and simmered for about 6 hours. Let the whole be then put into a conical bag of linen to separate the clear liquor, and wash the residuum till the water ceases to taste acid. Evaporate the strained liquor, and when reduced to about half its bulk, let it cool. A white sediment will form which must be allowed to subside ; the clear solution must be decanted, and boiled to dryness in a glass vessel. A white mass will remain, which may be fused in a platinum crucible, and poured out into a clean copper dish. A transparent *glass* is obtained, consisting of phosphoric acid with some phosphate, and a little sulphate of lime.

355. Phosphoric acid is a deliquescent substance, and when in the flocculent state, as obtained by burning phosphorus under a dry bell-glass, it dissolves in water with a hissing noise and excites great heat when a small particle is put upon the tongue ; when fused it has been called *glacial phosphoric acid.* It is inodorous, very sour, volatile at a bright red heat, but unchanged by it. As commonly prepared, it is an unctuous fluid. Specific gravity = 2. (Thomson's chem. gives 2.687 for dry phosphoric acid.)

356. The composition of these acids of phosphorus has been variously given by different chemists. Sir H. Davy's most recent experiments upon this subject, (*Phil. Trans.* 1818,) appear to furnish the least exceptionable results, and he has stated them thus :

Hypophosphorous acid,	Phosphorus 45,	Oxygen 15
Phosphorous acid	45	30
Phosphoric acid	45	60

If these numbers be reduced to the equivalents which I have employed, the number representing phosphorus would be 12. The hypophosphorous acid would then consist of two proportionals of phosphorus = 24, and one proportional of oxygen = 8. The phosphorous acid of one of oxygen and one of phosphorous ; and the phosphoric of one and two.

From some experiments which I made in 1816 upon the quantity of oxygen absorbed by phosphorus during its conversion into phosphoric acid, by burning it in great excess of oxygen, I was induced to believe that, at mean temperature and pressure, each grain of phosphorus condensed rather less than 4.5 cubic inches of oxygen, which would give a result differing from that of Sir H. Davy. On the whole, however, I am inclined to believe the results of his experiments less liable to fallacy than my own; and adopting the number 12 as representative of phosphorus, the phosphorous acid will consist of one proportional of phosphorus = 12, and one of oxygen = 8, and will be represented by the number 20: and the phosphoric acid containing one proportional of phosphorus and two of oxygen, 12 + 16, will be represented by 28.

357. When phosphorus is exposed to a moist atmosphere, it undergoes an apparent deliquescence, producing a sour liquid composed of phosphorous and phosphoric acids and water. M. Dulong has called this *phosphatic acid.*

358. *Phosphite of Ammonia* may be obtained in delicate tabular crystals, decomposable by heat, and very soluble.

359. *Hypophosphite of Ammonia* has not been examined.

Union with ammonia.

360. *Phosphate of Ammonia* is a common ingredient in the urine of carnivorous animals. It may be obtained pure by saturating phosphoric acid with ammonia; it forms permanent octoëdral crystals soluble in two parts of water at 60°, and of a bitterish saline taste, specific gravity 1.8051. (Thomson's chem:)—

It consists of . . . . 28 acid
17 ammonia
—
45

This salt is the best source of pure phosphoric acid, for if it be exposed to a red heat in a platinum vessel, the ammonia evaporates, and the acid is obtained in the form of a transparent glass, very deliquescent and pure. The phosphate of ammonia for this purpose may be conveniently and economically prepared by saturating the impure acid obtained from bones (354) with carbonate of ammonia, filtering and evaporating to dryness.

Union with chlorine.

361. *Phosphorus and Chlorine.*—These elements unite in two proportions, forming two definite compounds, the *chloride* and *perchloride* of phosphorus.

362. When phosphorus is submitted to the action of chlorine, it burns with a pale yellow flame, and produces a white volatile compound, which attaches itself to the interior of the vessel, and which is the *perchloride of phosphorus.* This substance was long mistaken for phosphoric acid, but its easy volatility is alone sufficient distinction; it rises in vapour at 200°. It is fusible and crystallizable: and when brought into the contact of water, a mutual decomposition is effected, (366) and phosphoric and muriatic acids result. When passed through a red-hot porcelain tube with oxygen, phosphoric acid is produced and chlorine evolved, which shows that oxygen has a stronger attraction for phosphorus than chlorine.

When phosphorus is burned in chlorine, one grain absorbs 8 cubic inches; so that the compound formed must be regarded as containing 1 proportional of phosphorus, and 2 of chlorine, or 12 of phosphorus + 72 of chlorine, and its number is 84.

363. With ammonia perchloride of phosphorus forms a singular compound, which, though consisting of three volatile bodies, remains unchanged at a white heat, and is insoluble in water.

364. *Chloride of Phosphorus*, consisting of 12 phosphorus + 36 chlorine, is procured by distilling a mixture of phosphorus and *corrosive sublimate*, which is a perchloride of mercury. In this experiment *calomel*, or protochloride of mercury, is formed, and the phosphorus combines with one proportional of chlorine.

365. The chloride of phosphorus, when first obtained, is a liquid of a reddish colour: but it soon deposits a portion of phosphorus, and becomes limpid and colourless. Its specific gravity is 1.45. Exposed to the air it exhales acid fumes: it does not change the colour of dry vegetable blues. Chlorine converts it into perchloride. Ammonia separates phosphorus, and produces the singular triple compound before adverted to (363.)

366. Chloride of phosphorus acts upon water with great energy, and produces muriatic and *phosphorous* acids, while the perchloride produces muriatic and *phosphoric* acids: for, as in the perchloride there are two proportionals of chlorine, so in acting upon water, two of oxygen must be evolved, which uniting to one of phosphorus generate phosphoric acid. The chloride of phosphorus, on the contrary, containing only one proportional of chlorine, produces muriatic acid and phosphorous acid, when it decomposes water, as the following tables show:

Before decomposition.

$$\left.\begin{array}{l}1\ \text{Chlorine} = 36\\ 1\ \text{Phospho.} = 12\end{array}\right\}\overset{\text{Chloride of Phosp.}}{48.}\ \Bigg|\ \left.\begin{array}{l}1\ \text{Hydrog.} = 1\\ 1\ \text{Oxygen} = 8.\end{array}\right\}\overset{\text{Water.}}{9}$$

After decomposition.

$$\left.\begin{array}{l}1\ \text{Chlorine} = 36\\ 1\ \text{Hydrog.} = 1\end{array}\right\}\overset{\text{Muriatic Acid.}}{37}\ \Bigg|\ \left.\begin{array}{l}1\ \text{Phospho.} = 12\\ 1\ \text{Oxygen} = 8\end{array}\right\}\overset{\text{Phosphorous Acid.}}{20}$$

But the phosphorous acid, thus produced, always contains water, which it throws off when heated in ammonia, forming, with that alcali, a dry phosphite. This experiment shows that the *hydrophosphorous acid* consists of 2 proportionals of phosphorous acid = 40 + 1 water = 9, its number is therefore, 49.

Union with iodine. 367. *Phosphorus and Iodine.*—When these substances are brought together in an exhausted vessel, they act violently, and form a reddish compound; the *iodide of phosphorus* decomposes water with great energy, and produces phosphorous and hydriodic acids (257.) It consists of 12 phosphorus + 125, iodine = 137.

368. *Periodide of phosphorus* is a black compound, formed by heating one part of phosphorus with rather more than 20 of iodine. It consists according to Dr. Thomson, of 1 proportional of phosphorus + 2 of iodine. It does not decompose water.

Union with hydrogen. 369. *Phosphorus and Hydrogen.—Phosphuretted Hydrogen.—Hydroguret of Phosphorus.*—When phosphorus is presented to nascent hydrogen, two gaseous compounds result. The one inflames spontaneously upon the contact of the atmosphere. This may be procured by heating phosphorus in a solution of caustic potassa; or better, by acting upon *phosphuret of lime* (636) by dilute muriatic acid. In the former case about a quarter of an ounce of phosphorus should be introduced into a small retort, capable of holding about four ounces of water; it should then be completely filled with a moderately strong solution of potassa, and the beak being placed under the shelf of the pneumatic apparatus, the heat of an Argand lamp carefully applied till it boils: gas will gradually be generated so as to expel a portion of the alcaline solution, and ultimately to bubble up through the water.

370. For obtaining this gas by the second process, Dr. Thomson gives the following directions: Fill a small retort with water acidulated by muriatic acid, and then throw into it a quantity of phosphuret of lime in lumps. Plunge the beak of the retort under water, and place over it an inverted jar filled with that liquid. Phosphuretted hydrogen gas is extricated in considerable quantity, and soon fills the glass jar. Half an ounce of phosphuret of lime yields about 70 cubic inches of this gas.—THOMSON'S *System*, Vol. i., 272.

371. This gas is colourless, has a nauseous odour like onions, a very bitter taste and inflames when mixed with air, a property which it loses by being kept over water; water takes up about two *per cent.* of this gas, and acquires a bitter taste, and the smell of onions.

372. When bubbles of phosphuretted hydrogen are sent up into a jar of oxygen, they burn with greatly increased splendour; in chlorine too they burn with a beautiful pale blue light, forming muriatic acid and perchloride of phosphorus. In a narrow tube it may be mixed with oxygen without exploding, in which case it is deprived of its phosphorus without suffering any change of bulk. It burns when thrown up into nitrous oxide.

373. For our knowledge of the composition of this gas, we are chiefly indebted to Dr. Thomson, who has shown that the hydrogen suffers no change of bulk in uniting to the phosphorus; so that the difference of weight between this gas and pure hydrogen, indicates the weight of phosphorus: 100 cubic inches of phosphuretted hydrogen weigh 27.527 grains; hence the gas may be regarded as containing one proportional of phosphorus and one of hydrogen, or $12+1=13$*.

When phosphuretted hydrogen is mixed with oxygen, it requires a volume and a half of the latter gas for its perfect combustion; and as the hydrogen would require half its volume of oxygen for the production of water, the remaining volume must unite to the phosphorus to produce phosphoric acid.

374. *Bihydroguret of Phosphorus.—Hydrophosphoric Gas.*—The next compound of phosphorus and hydrogen has been called, by Sir H. Davy, *hydrophosphoric gas*. It is procured by heating the solid hydrophosphorus acid in a very small retort. The gas must be collected over mercury, for water absorbs one-eighth its volume. Its specific gravity to hydrogen is as 14 to 1. 100 cubical inches weigh 29.645 grains. It is not spontaneously inflammable, but explodes when heated with oxygen. It inflames spontaneously in chlorine, one volume requiring four of chlorine for its perfect combustion. Its smell is less disagreeable than the former. It consists of 2 of hydrogen and 1 of phosphorus $\overset{H}{2}+\overset{P}{12}=14$; but the two volumes of hydrogen are

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* When sp. gr. of oxygen = 1, that of phosphorus hydrogen = 0.8125, this multiplied by 2 gives 1.625 for the atom of phos. hyd. also 1.625 is just 13 times 0.125 (atom of hydrogen.)

condensed into one; consequently, when the gas is decomposed, as for instance, by subliming sulphur in it, two volumes of sulphuretted hydrogen are formed*.

375. When hydrophosphorous acid is decomposed for the production of this gas, phosphoric acid is always generated. Hydrophosphorous acid has been stated (366) to contain two proportionals of phospherous acid + one of water. Hence the elements

$$\left.\begin{array}{l}24 \text{ phosphorus}\\ 16 \text{ oxygen}\end{array}\right\} = \text{phosphorous acid,}$$

$$\left.\begin{array}{r}8 \text{ do.}\\ 1 \text{ hydrogen}\end{array}\right\} = \text{water,}$$

or 49.0 parts of hydrophosphorous acid contain
24 phosphorus
24 oxygen
1 hydrogen.

The three proportionals of oxygen = 24, will require one proportional and a half of phosphorus = 18, to form phosphoric acid; and the remaining half proportional of phosphorus will unite to the one of hydrogen to form hydrophosphoric gas.

To avoid fractions the phænomena may be stated thus:

Four proportionals of hydrophosphoric acid contain

4 phosphorus		=	48
4 oxygen		=	32
2 do.	in the	=	16
2 hydrogen	water	=	2

The whole of the oxygen, amounting to 6 proportionals (*i. e.*, 8 × 6 = 48), unites to three proportionals of phosphorus (12 × 3 = 36), to form phosphoric acid. The two of hydrogen = 2, combine with the remaining proportional of phosphorus = 12 to form hydrophosphoric gas.

Union with nitrogen.

376. *Phosphorus and Nitrogen* produce no definite compound, though in some cases of animal decomposition the evolved nitrogen appears to hold phosphorus in solution.

Union with sulphur.

377. *Phosphorus and Sulphur* may be readily united by fusion in an exhausted vessel. When one proportional of phosphorus is united to one of sulphur (12 + 16), the compound bears a high temperature without decomposition. It is a crystallizable solid at temperatures below 50°.—FARADAY. *Journal of Science*, Vol. iv. p. 361.

378. By acting upon fused phosphorus by the Voltaic spark, it always affords a small portion of hydrogen gas; this gas is also evolved from it, as from sulphur (343) during its union with some of the metals.

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SECTION V. *Carbon.*

Diamond.

379. THE purest form of this elementary substance is the diamond, a mineral body first discovered in Asia, in the provinces of Golconda

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[*] Sp. gr. of this gas to oxygen is as 875: 1 now 0.875 × 2 = 1.75 the atom of bihydrog. phos:—this 1.75 is just 14 times 0.125 or the atom of hydrogen.

and Visapour in Bengal, and in the island of Borneo. About the year 1720, diamonds were first found in the district of Serra Dofrio, in Brazil. They always occur in detached crystals in alluvial soil. The primitive form of the diamond is the regular octoëdron, each triangular facet of which is sometimes replaced by six secondary triangles, bounded by curved lines; so that the crystal become spheroidal, and presents 48 facets. Diamonds, with 12 and 24 facets, are not uncommon. (JAMESON'S *Mineralogy*, 2d edit. Vol. i. p. 1). The diamond has been found nearly of all colours: those which are colourless are most esteemed; then those of a decided red, blue, or green tint. Black diamonds are extremely rare. Those which are slightly brown, or tinged only with other colours, are least valuable. The fracture of the diamond is foliated, its laminæ being parallel to the sides of a regular octoëdron. It is brittle and very hard; its specific gravity is 3.5.

380. The art of cutting and polishing diamonds, though probably of remote antiquity in Asia, was first introduced into Europe, in 1456, by Louis Berghen, of Bruges, who accidentally discovered that by rubbing two diamonds together, a new facet was produced. The particular process of forming the rough gems into *brilliants* and *rose diamonds* has been described at length by Jeffries, (*Treatise on Diamonds and Pearls*, 3d edit. London, 1800). By either of these processes, but especially by the former, so much is cut away that the weight of the polished gem does not exceed half that of the rough stone; so that the value of a cut diamond is esteemed equal to that of a similar rough diamond of twice the weight, exclusive of the cost of workmanship. The weight, and therefore the value of diamonds, is estimated in *carats*, 150 of which are about equal to one ounce troy, or 480 grains. They are divided into halves, quarters, or carat grains, eighth, sixteenth, and thirty-second parts.

381. The difference of value between one diamond and another, is, generally speaking, as the squares of their respective weights: thus, the value of three diamonds, of one, two, and three carats' weight respectively, is as one, four, and nine. The average price of rough diamonds is estimated by Jeffries, at £2. per carat; and, consequently, when wrought, the cost of the first carat, exclusive of workmanship, will be £8., which is the value of a rough diamond of two carats.

	£
A wrought diamond of three carats is worth	72
4 carats	128
5 ditto	200
10 ditto	800
20 ditto	3,200
30 ditto	7,200
40 ditto	12,800
50 ditto	20,000
60 ditto	28,800
100 ditto	80,000

This mode of valuation, however, only applies to small diamonds, in consequence of the difficulty of finding purchasers for the larger ones.

382. The largest known diamond is probably that mentioned by Tavernier, in the possession of the Great Mogul. Its size is about that of half an hen's egg; it is cut in the rose form, and when rough, is said to have weighed 900 carats. It was found in Golconda about the year 1550.

Among the crown jewels of Russia is a magnificent diamond, weighing 195 carats. It is the size of a small pigeon's egg, and was formerly the eye of a Brahminical idol, whence it was purloined by a French soldier; it passed through several hands, and was ultimately purchased by the Empress Catharine for the sum of £90,000 in ready money and an annuity of £4,000.

Perhaps the most perfect and beautiful diamond hitherto found, is a brilliant brought from India by an English gentleman of the name of Pitt, who sold it to the Regent Duke of Orleans, by whom it was placed among the crown jewels of France. It weighs rather more than 136 carats, and was purchased for £100,000.

383. Another form of carbon is *charcoal*, the purest variety of which is *lamp-black*.

Method of preparing charcoal. Charcoal may be prepared by heating pieces of wood, covered with sand, to redness, and keeping them in that state for about an hour. They are converted into a black brittle substance, which appears to be the same from whatever kind of wood it has been procured.

Common charcoal employed as fuel is usually made of oak, chesnut, elm, beech, or ash wood, the white and resinous woods being seldom used. Young wood affords a better charcoal than large timber, which is also too valuable to be thus employed. It is formed into a conical pile, which being covered with earth or clay, is suffered to burn with a limited access of atmospheric air, by which its complete combustion, or reduction to ashes, is prevented.

Another, and a more perfect mode of preparing charcoal, consists in submitting it to a red heat in a kind of distillatory apparatus consisting of cast iron cylinders, from which issue one or more tubes for the escape of gaseous matters. The makers of gunpowder particularly prefer this process. (A plate of this apparatus is given by Mr. Parkes, in his *Chemical Essays*.)

385. Lamp-black is prepared principally by turpentine manufacturers from refuse and residuary resin, which is burned in a furnace, so constructed, that the dense smoke arising from it may pass into chambers hung with sacking, where the soot is deposited, and from time to time swept off, and sold without any further preparation. (Aikin's *Dictionary*. Art. Charcoal.) When lamp-black has been heated red hot in a close vessel, it may be considered as very pure carbon.

386. The quantity of charcoal obtained from different kinds of wood is liable to much variation. From 100 parts of the following woods, Messrs. Allen and Pepys obtained the annexed quantities of charcoal. —*Phil. Trans.* 1807.

Beech	15.00	Oak	17.40
Mahogany	15.75	Fir	18.17
Lignum Vitæ	17.25	Box	20.25

Its properties. 387. Charcoal is a black, insoluble, inodorous, insipid, brittle substance; an excellent conductor of electricity, but a bad conductor of heat; unchanged by the combined action of air and moisture at common temperatures; infusible; and easily combustible in oxygen gas. It is capable of destroying the smell and taste of a variety of vegetable and animal substances. (Lowitz, *Crell's Annals*, Vol. ii. p. 165). The use of charring piles; of throwing charcoal into putrid water; of wrapping it in clothes that have accquired a bad smell; of adding it to port wine, with a view of making it tawny; depends upon the above properties.

388. Newly-made charcoal has the property of absorbing certain quantities of the different gases. Upon this subject the experiments of M. Theodore de Saussure are the most recent. (THOMSON'S *Annals*, Vol. vi.) The charcoal was heated red hot, then suffered to cool under mercury, and introduced into the gas. The following are the volumes of different gases absorbed by a volume of charcoal = 1.

Ammonia	90	Bicarburetted hydrogen	35
Muriatic acid	85	Carbonic oxide	9.42
Sulphurous acid	65	Oxygen	9.25
Sulphuretted hydrogen	55	Nitrogen	7.5
Nitrous oxide	40	Carburetted hydrogen	5
Carbonic acid	35	Hydrogen	1.75

The absorption was always at its maximum at the end of 24 hours.

389. The results of these experiments are widely different from those of Count Morozzo, (*Journal de Physique*, 1783) and of M. Rouppe (*Annales de Chimie*, Vol. xxxii.) It would also appear, that this property depends upon the mechanical texture of the charcoal, and consequently will vary in the different woods; for by exposing the charcoal of different woods to air, Allen and Pepys found that they increased very differently in weight.

By a week's exposure, Charcoal from

Lignum Vitæ gained	9.6	per cent.
Fir	13.0	ditto
Box	14.0	ditto
Beech	16.3	ditto
Oak	16.5	ditto
Mahogany	18.0	ditto

The matter absorbed in these cases consisted principally of aqueous vapour, which is very greedily imbibed by newly-made charcoal.

390. *Carbon and Oxygen.*—There are two compounds of carbon and oxygen; the carbonic oxide and the carbonic acid. Union with oxygen.

391. *Carbonic Oxide* is usually obtained by subjecting carbonic acid to the action of substances which abstract a portion of its oxygen. Upon this principle, carbonic oxide gas is produced by heating in an iron retort a mixture of chalk and charcoal; or of equal weights of chalk and iron or zinc filings. It is also obtained by heating a mixture of equal parts of oxide of zinc, and charcoal; but the mixture that affords it most pure, is equal parts of carbonate of baryta and clean iron filings; these should be introduced into a small earthen retort, so as nearly to fill it, and exposed to a red heat: the first portion of gas being rejected as mixed with the air of the retort, it may afterwards be collected quite pure. The gas should be well washed with lime-water, and may be preserved over water. The nature of this gas was first made known by Mr. Cruickshanks, of Woolwich, in 1802 (NICHOLSON'S 4to *Journal*, v.); and about the same time it was examined by Messrs. Clement and Desormes. *Annales de Chimie*, xxxix.

392. Its specific gravity to hydrogen is as 14 to 1; 100 cubical inches weighing 29.63 grains*. It is fatal to animals extinguishes flame, and burns with a pale blue lambent light, when mixed with, or exposed to atmospheric air.

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* Specific gravity of oxygen: specific gravity of carbonic oxide : : 1 : 0.875, and 0.875 × 2 = 1.75 the atom of carbonic oxide, also 1.75 is just 14 times 0.125.

393. When a stream of carbonic oxide is burnt under a dry bell-glass of air or oxygen, no moisture whatever is deposited, showing that it contains no hydrogen.

394. When two volumes of carbonic oxide, and one of oxygen, are acted on by the electric spark, a detonation ensues, and two volumes of carbonic acid are produced. Whence it appears, that carbonic acid contains just twice as much oxygen as carbonic oxide, which may be considered as a compound of one volume of oxygen and one volume of gaseous carbon; or of one proportional of carbon and one of oxygen, the latter being so expanded as to occupy two volumes.

395. Carbonic oxide suffers no change by being passed and repassed through a red-hot porcelain tube; nor is it decomposed at high temperatures by phosphorus, sulphur, nor even, according to the experiments of Saussure, by hydrogen. (*Journal de Physique*, lv.) None of the metals exert any action upon this gas, except potassium and sodium, which, at a red heat, burn in it by abstracting its oxygen, and carbon is deposited.

396. The representative number of carbon, as obtained by considering this gas a compound of one proportional, of carbon vapour and one of oxygen, is 6; and 6 carbon + 8 oxygen = 14 carbonic oxide.

Union with chlorine. 397. Carbonic oxide and chlorine combine and produce *Chlorocarbonic acid* or, *Phosgene gas*, as it has been termed by its discoverer Dr. John Davy, in consequence of the mode of its production.

By exposing a mixture of equal volumes of chlorine and carbonic oxide to the action of light, a condensation =[*]0.5 takes place. The compound has a peculiar pungent odour. It is soluble in water, and is resolved into carbonic and muriatic acid gases. The weight of chloro-carbonic acid to hydrogen is as 50 to 1. 100 cubical inches weigh 105.85 grains. It condenses four times its volume of ammoniacal gas, producing a peculiar compound of a white colour.—*Phil. Trans.* 1807.

[†]398. *Carbonic acid* may be obtained by burning carbon, either pure charcoal or the diamond, in oxygen gas: the oxygen suffers no change of bulk, so that the composition of carbonic acid is easily learned by comparing its weight with that of an equal volume of pure oxygen. 100 cubic inches of oxygen weigh 33.88 grains: 100 cubic inches of carbonic acid weigh 46.57 grains, or just 22 times as heavy as hydrogen, hence 100 cubical inches of carbonic acid must consist of 33.88 grains of oxygen, + 12.70 grains of carbon, and 12.7 : 33.88 : : 6 : 16. Hence 1 proportional of charcoal = 6 + 2 propor-

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[*] Specific gravity 3.125 (oxygen = 1); 3.125 × 2 = 6.25 the atom, also, 125 × 5 = 6.25, the following diagram will denote its composition.

Chlorine.	Carbonic oxide.	=	Chlorocarbonic acid.
36	14		50

[†] The sp. gr. of Carb. acid compared with oxygen, is as 1.375 : 1; now 1.375 × 2 = 275, (the atom) also 2.75 is just 22 times the atom (0.125) of hydrogen.

Carbon vapour.	Oxygen.	Carbonic acid.
6	8 + 8 = 16	= 22.

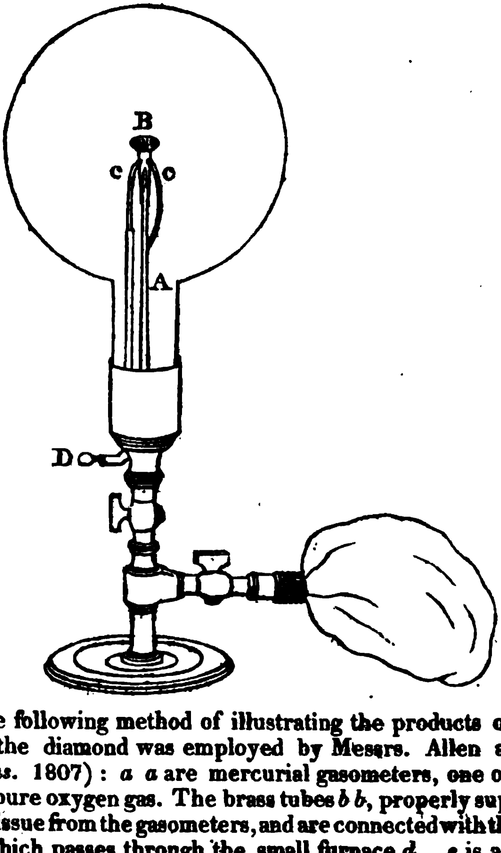
tionals of oxygen = 16 will constitute carbonic acid, represented by the number 22, or by the following symbol.

399. It is not evident to whom the combustibility of the diamond first occurred; but in the year 1694 the Florentine Academicians proved its destructibility by heat by means of a burning lens. The *products* of its combustion were first examined by Lavoisier in 1772, and subsequently with more precision by Guyton Morveau, in 1785. (*Annales de Chimie*, xxxi.) In 1797, Mr. Tennant demonstrated the important fact, that when equal weights of diamond and pure charcoal were submitted to the action of red hot nitre, the results were in both cases the same; and in 1807 the combustion of the diamond in pure oxygen was found by Messrs. Allen and Pepys to be attended with precisely the same results as the combustion of pure charcoal. Hence the inevitable inference that charcoal and the diamond are similar substances in their chemical nature, differing only in mechanical texture.

400. The following apparatus may be conveniently employed for exhibiting the results of the combustion of the diamond. It consists of a glass globe, of the capacity of about 140 cubical inches, furnished with a cap, having a large aperture; the stop-cock, which screws into this cap, has a jet, A, rising from it, nearly into the centre of the globe; this is destined to convey a small stream of hydrogen, or other inflammable gas. Two wires, *c c*, terminate at a very little distance from each other, just above this jet, and are intended to inflame the stream of hydrogen by electrical sparks; one of them commences from the side of the jet, the other is enclosed and insulated nearly in its whole length in a glass tube: the tube and wire pass through the upper part of the stop-cock, and the wire terminates on the outside in a ball or ring, D, at which sparks are to be taken from the machine, either directly or by a chain. On the end of the jet is fixed, by a little socket, a small capsule, B, made of platinum foil. This capsule is pierced full of small holes, and serves as a grate to hold the diamonds. Its distance is about three-quarters of an inch from the end of the jet; and the arm, by which it is supported, is bent round, so that the stream of hydrogen shall not play against it. The stop-cock screws, by its lower termination on to a small pillar, fixed on a stand, and at the side of this pillar is an aperture by which a bladder filled with gas may be connected with the apparatus.

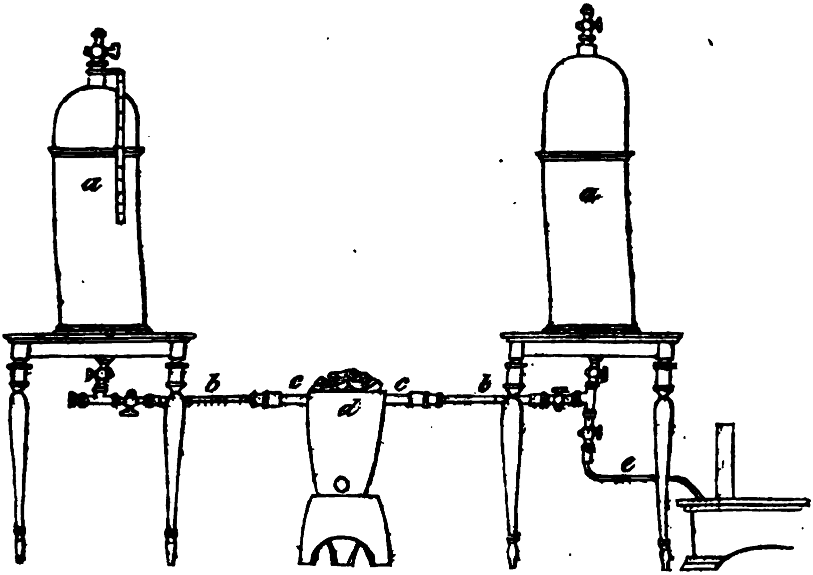
On using the apparatus, the diamond is to be placed in the capsule; and then the globe being screwed on to the stop-cock, the latter is to be removed from the pillar and placed on the air-pump; the globe is then to be exhausted, and afterwards filled with pure oxygen: or, lest the stream of oxygen in entering should blow away the diamond, the globe may be filled with the gas first, and then, dexterously taking out the stop-cock for a short time, the diamonds may be introduced and the stop-cock replaced. The apparatus is then to be fixed on the pillar, and a bladder of hydrogen gas attached to the aperture. Now, passing a current of sparks between the wires, a small stream of hydrogen is to be thrown in, which inflaming, immediately heats the capsule and diamonds white hot; the diamonds will then enter into combustion, and the hydrogen may be immediately turned off and the bladder detached. The diamonds will continue to burn, producing a strong white heat, until so far reduced in size as to be cooled too low by the platinum with which they lie in contact.

When the flame of hydrogen is used to heat the diamonds, it is evident a little water will be found in the globe, but this is of no consequence except in attempts to detect hydrogen in the diamond; the inconvenience may be obviated, if required, by using the flame of carbonic oxide. As, however, no hydrogen has at any time been detected in the diamond, it is better to use that gas as the heating agent; for then the carbonic acid, produced by the combustion, is unmixed with that from any other source, and may be collected, and its quantity ascertained.



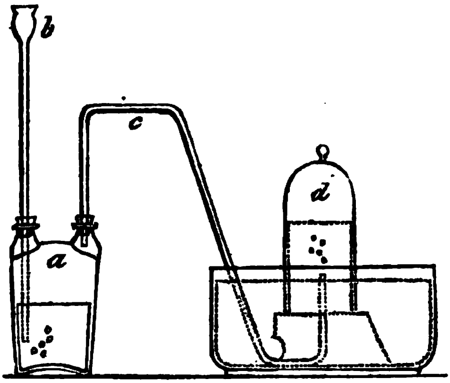
401. The following method of illustrating the products of the combustion of the diamond was employed by Messrs. Allen and Pepy's (*Phil. Trans.* 1807): *a a* are mercurial gasometers, one of which is filled with pure oxygen gas. The brass tubes *b b*, properly supplied with stop-cocks issue from the gasometers, and are connected with the platinum tube *c c*, which passes through the small furnace *d*. *e* is a glass tube passing into the mercurio-pneumatic apparatus by which the gas may

be drawn out of the gasometers into convenient receivers. A given weight of diamond is introduced into the centre of the platinum tube, which is then heated to bright redness, and the gas passed over it, backwards and forwards, by alternately compressing the gasometers. Carbonic acid is soon formed, and it will be found that the increase of weight sustained by the oxygen is equivalent to that lost by the diamond; that the oxygen undergoes no change of bulk; and that the results are, in all respects, similar to those obtained by a similar combustion of perfectly pure charcoal.



402. Carbonic acid is a most abundant natural product; the best mode of procuring it for experiment consists in acting upon marble (643) (*carbonate of lime*) by dilute muriatic acid.

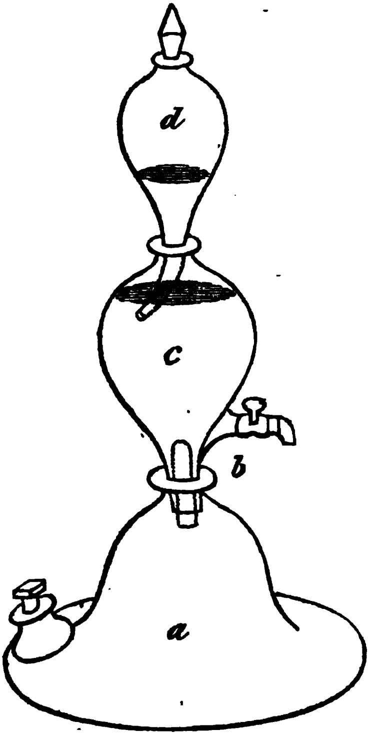
For this purpose the marble, in small fragments, is introduced into the two-necked bottle *a*, and covered with water; muriatic acid is then slowly poured down the funnel *b*, which causes an immediate effervescence, and the gas passes through the bent tube *c*, into the inverted jar *d*. When the action ceases, it may be renewed by the addition of fresh acid, until the whole of the marble is dissolved.



Properties of carbonic acid.

403. Carbonic acid may be collected over water, but must be preserved in vessels with glass-stoppers, since water, at common temperature and pressure, takes up its own volume : under a pressure of two atmospheres it dissolves twice its volume, and so on. It thus becomes brisk and tart, and reddens delicate vegetable blues. By freezing, boiling, or exposure to the vacuum of the air-pump, the gas is given off.

404. The effervescent quality of many mineral waters is referable to the presence of this gas, and they are often imitated by condensing carbonic acid into water, either by a condensing pump, of which a description is given by Mr. Pepys (*Quarterly Journal of Science and Arts*, Vol. iv. p. 305) or by a Nooth's apparatus, as represented in the following wood-cut. It consists of three vessels, the lowest, *a*, flat and broad, so as to form a steady support; it contains the materials for evolving the gas, such as pieces of marble and dilute muriatic acid, of which fresh supplies may occasionally be introduced through the stopped aperture. The gas passes through the tube *b*, in which is a glass valve opening upwards, into the vessel *c*, containing the water or solution intended to be saturated with the gas, and which may occasionally be drawn off by the glass stop-cock. Into this dips the tube of the uppermost vessel *d*, which occasions some pressure on the gas in *c*, and also produces a circulation and agitation of the water. At the top of *d* is a heavy conical stopper, which acts as an occasional valve, and keeps up a degree of pressure in the vessels.



Nooth's apparatus.

405. Carbonic acid is unrespirable, and it extinguishes flame. Its weight may be shown by placing a lighted taper at the bottom of a tall glass jar, and then pouring the gas out of a bottle into it, in the manner of a liquid; it descends and extinguishes the flame, and will remain a long time in the lower part of the vessel. Hence in wells, and in some caverns, carbonic acid frequently occupies the lower parts, while the upper parts are free from it. The miners call it *choak damp*.

406. The presence of carbonic acid is instantly detected by *lime water* (621), which it renders turbid, and causes a deposit of a white matter, which is *carbonate of lime*. The addition of water, saturated with carbonic acid, to lime water, also occasions a milkiness from the same cause. If excess, either of the gas or of its aqueous solution, be added to the lime water, the precipitate is re-dissolved, carbonate of lime being soluble in carbonic acid (642.)

407. As all common combustibles, such as coal, wood, oil, wax, tallow, *&c.*, contain carbon as one of their component parts, so the combustion of these bodies is always attended by the production of carbonic acid. It is also produced by the respiration of animals; hence it is detected, often in considerable proportion, in crowded and illuminated rooms, which are ill ventilated, and occasions difficulty of breathing, giddiness, and faintness. In the atmosphere it may also be detected (303), varying in quantity from 1 to 0.1 *per cent.*

408. As carbonic acid is usually retained in combination by very

feeble affinity, so it is evolved from most of the *carbonates* by the simple operation of heat. Thus chalk, when heated, gives out carbonic acid, and becomes *quicklime*. It is also evolved from its combinations by most of the other acids; and if nitric, muriatic, or sulphuric acid, be poured upon the carbonates, the presence of carbonic acid is indicated by *effervescence*.

409. In Section 398, the nature of carbonic acid has been synthetically demonstrated. It may be analyzed by the action of the metal *potassium*, which is capable of abstracting its oxygen, and, with the aid of heat, burns in it with great splendour; charcoal is deposited, and an *oxide of potassium* is formed. In this and in some other cases, oxygen is seen alternately producing acid and alcali. If carbonic acid, obtained by burning the diamond in oxygen, be thus decomposed by potassium, the carbon makes its appearance in the form of charcoal, equal in weight to the diamond consumed.

410. There are some other substances which at high temperatures, are capable of decomposing carbonic acid, and abstracting part of its oxygen; thus, if a mixture of two parts of hydrogen and one of carbonic acid, by volume, be passed through a red-hot tube in the apparatus represented at page 99, water is formed, and carbonic oxide passes into the receiver *d*, mixed with the excess of hydrogen.

411. If carbonic acid be passed over red-hot charcoal, it becomes converted into carbonic oxide by taking up an additional proportion of base. The blue flame, often seen upon the surface of a charcoal fire, arises from the combustion of the carbonic oxide formed in this way; the air entering at bottom, forms carbonic acid, which, passing through the red-hot charcoal, becomes converted into carbonic oxide.

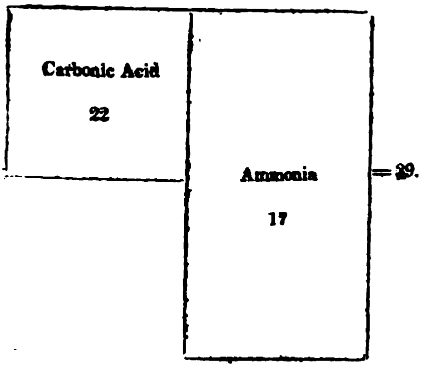
412. At a bright red heat, iron decomposes carbonic acid, by abstracting a portion of its oxygen, and forming oxide of iron and carbonic oxide.

Union with ammonia.

413. *Carbonic acid and ammonia—Carbonate of ammonia.*—These gases readily combine, and produce one of the most useful and best known of the ammoniacal compounds.

When one volume of carbonic acid and two volumes of ammonia are mixed in a glass vessel, over mercury, a complete condensation ensues, and a *carbonate of ammonia* is produced.

It consists of 17 ammonia + 22 carbonic acid, and is represented by 39.

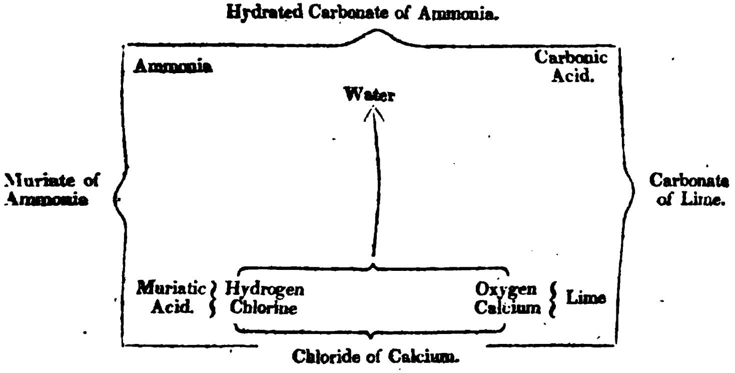


414. If water be present, it so far overcomes the elasticity of the gas, as to enable the salt formed to take up another volume of carbonic acid, and thus a *bicarbonate* is formed.

415. Carbonate of ammonia crystallizes in octoëdrons, though it is generally met with in cakes broken out of the subliming vessel, being obtained by sublimation from a mixture of muriate of ammonia and carbonate of lime.

The results, however, of this decomposition are not strictly speaking, carbonate of ammonia and muriate of lime, but carbonate of ammonia, water, and chloride of calcium, the two former being in combination, so that a *hydrated carbonate of ammonia* is always obtained.

Supposing the materials perfectly dry, the water is formed by the union of the hydrogen of the muriatic acid with the oxygen of the lime, as shown in the following diagram :



416. Mr. Richard Phillips has shown (*Quarterly Journal*, vii. 294) that the carbonate of ammonia of commerce, the *ammoniæ subcarbonas* of the *Pharmacopæia*, is a compound of

3 Proportionals of	Carbonic acid	22	× 3 =	66
2 Ditto	Ammonia	17	× 2 =	34
2 Ditto	Water	9	× 2 =	18
				118

Its odour is pungent ; its taste hot and saline ; it reddens turmeric, and renders blues green. A pint of water at 60° dissolves rather less than 4 ounces. This solution is directed in the *Pharmacopæia*, under the name of *Liquor Ammoniæ Subcarbonatis*.

417. By exposure to air, carbonate of ammonia loses its odour, and ceases to act upon turmeric paper. In this state it may be considered as an *hydrated bicarbonate of ammonia*, and is composed, according to Phillips, of

2 Proportionals of	Carbonic acid . .	22	× 2 =	44
1 Ditto	Ammonia		=	17
2 Ditto	Water	9	× 2 =	18
				79

Omitting the water, therefore, it appears that there are three compounds of carbonic acid and ammonia. The carbonate composed of 1 proportional acid + 1 base; the sesqui-carbonate composed of 1.5 acid + 1 base; and the bi-carbonate of 2 acid + 1 base.

Union of carbon and chlorine.

418. *Carbon and Chlorine.*—Mr. Faraday has ascertained that, by exposing carburetted hydrogen, mixed with great excess of chlorine, to the action of light, a white crystalline substance is formed, which, when purified by washing with water, is a *perchloride of carbon.* This substance is nearly tasteless; its odour resembles camphor; its specific gravity is about 2; it is a nonconductor of electricity. It is volatile, and in close vessels fuses at 320°, and boils at 360°. It is not very combustible, but burns when held in the flame of a spirit lamp, with the emission of much smoke and acid fumes. It is insoluble in water, but readily soluble in alcohol and ether; these solutions deposit arborescent and quadrangular crystals. It also dissolves in volatile and fixed oils. It is scarcely acted upon by alcaline and acid solutions; but most of the metals decompose this substance at a red heat. Potassium burns brilliantly in its vapour, causing the deposition of carbon, and the production of chloride of potassium. The metallic oxides also decompose it at high temperatures, producing metallic chlorides, and carbonic acid or oxide, according to the proportion of oxygen present; no water is produced, showing the absence of hydrogen in the compound. It appears, from various analytical experiments upon this compound, among which may be mentioned its decomposition, by passing it through red-hot peroxide of copper, that 100 parts afford 10 carbon + 90 chlorine; whence it would appear to consist of

2 Proportionals of Carbon	6 × 2 =	12
3 Ditto Chlorine	36 × 3 =	108
		120

419. When the above perchloride of carbon is passed through a red-hot tube, containing fragments of rock-crystal to increase the heated surface, it gives off a portion of chlorine, and is converted into a liquid *protochloride of carbon.* It is a limpid colourless fluid, specific gravity 1.55, and not combustible, except retained in the flame of the spirit-lamp, when it burns with a yellow flame, much smoke, and fumes of muriatic acid. It does not congeal at 0°; it rises in vapour at about 165°. It is insoluble in water, but soluble in alcohol, ether, and the oils. It is not affected by the acids or alcalis, nor at common temperatures, by solutions of silver. It dissolves chlorine, iodine, sulphur, and phosphorus. It affords, when decomposed, 17 carbon + 83 chlorine; whence it may be inferred to consist of

1 Proportional carbon	= 6
1 Ditto chlorine	= 36
	42

Union with hydrogen

420. *Carbon and Hydrogen—Carburetted Hydrogen—Olefiant Gas—Hydroguret of Carbon.*—Carbon and hydrogen combine and form olefiant gas, consisting of 1 proportional of carbon + 1 of hydrogen.*
Its composition will be 12 carbon } two volumes of each
2 hydrogen } condensed to one.
—
14

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* Its specific gravity compared with oxygen, as 0.875 : 1; now 0.875 × 2 = 1.75 (the atom,) also, 1.75 is just 14 times the atom (0.125) of hydrogen.

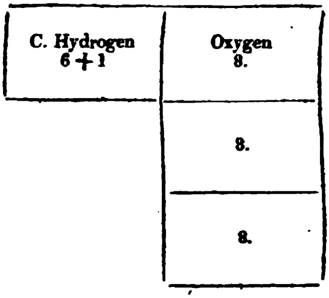
421. It is usually obtained by the decomposition of alcohol by sulphuric acid. For this purpose four parts of the acid and one of alcohol are put into a retort, and heated by a lamp. Soon after the mixture boils the gas is evolved. It may be collected over water; its specific gravity to hydrogen is 14. 100 cubic inches weigh 29.638 grains.

422. This gas is inflammable, burning with a bright yellowish white flame. One part by volume requires, for perfect combustion, three of oxygen, and two of carbonic acid are produced. When sulphur is heated in one volume of this gas, charcoal separates, and two volumes of sulphuretted hydrogen result. As hydrogen suffers no change of volume by combining with sulphur, it follows that olefiant gas contains two volumes of hydrogen condensed into one, hence the quantity of oxygen required for its combustion.

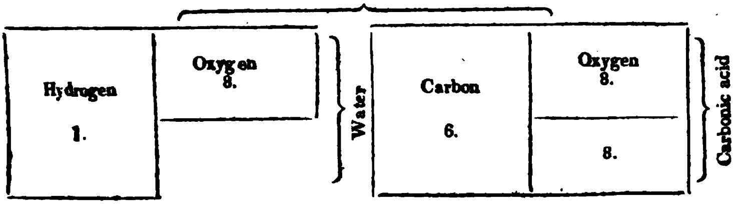
423. This gas is also decomposed by heat alone, as by passing and repassing it through a red-hot tube of earthenware or metal; it then deposits its carbon, and is expanded into twice its original volume of pure hydrogen.

424. The following symbols show that one volume or proportional of this gas, mixed with three of oxygen, are converted into water and carbonic acid, the hydrogen being expanded to two volumes, or its real bulk.

Before detonation.



After detonation.



This gas, therefore, is constituted of 1 proportional of carbon = 6 + 1 proportional of hydrogen = 1, and its number is 7.

425. When carburetted hydrogen is mixed with chlorine in the proportion of 1 to 2 by volume, the mixture on inflammation produces muriatic acid, and charcoal is abundantly deposited; but if the two gases be mixed in an exhausted vessel, or over water, they act slowly

upon each other, and a peculiar fluid is formed, which appears like a heavy oil; hence this compound has been termed *olefiant gas.*

426. *Chloric ether* is the term applied to this fluid by Dr. Thomson, who in 1810, ascertained that its component parts were chlorine and carburetted hydrogen. It has more lately been examined by M. M. Robiquet and Colin (*Annales de Chim. et Phys.* Vols. i. and ii.) The term *hydrochloride of carbon* may properly be applied to it. It may be formed by allowing a current of each gas to meet in a proper receiver; there should be excess of olefiant gas, for if the chlorine be in excess, the liquid absorbs it. It is transparent and colourless; its taste, sweet and somewhat acrid; its specific gravity = 1.2. It boils at 152°. It burns with a green flame, evolving muriatic acid, and largely depositing charcoal. As it is produced by equal volumes of chlorine and carburetted hydrogen, it is probably a compound of one proportional of chlorine and two of carburetted hydrogen; or of

Chlorine	36
Carbon	12
Hydrogen	2
	50

427. From some recent experiments made at the Royal Institution by Mr. Faraday, it appears that, by exposing this hydrochloride of carbon to the action of excess of chlorine, muriatic acid and chloride of carbon are the results.

Union with iodine.

428. When iodine and carburetted hydrogen are exposed to the action of light they combine, and form a *hydriodide of carbon.* This compound was first obtained in the Laboratory of the Royal Institution, by Mr. Faraday; and, reasoning analogically upon the facts already stated, in respect to the chloride of carbon, it is probable that it may lead to the discovery of an *iodide of carbon*, but that compound has not as yet been formed.

The hydriodide of carbon is a white crystalline solid, volatile without decomposition, and in many respects analogous to the hydrochloride of carbon; its taste is sweet and its odour aromatic.

429. A gas, containing carburetted hydrogen, is often generated in stagnant ponds; and by passing the vapour of water over red-hot charcoal, or by distilling moist charcoal in an iron retort, at a red heat, and washing the gas thus afforded in lime-water, by which the carbonic acid is separated, a similar compound is said to be obtained.

*The specific gravity of these gases is liable to great variation, 100 cubical inches weighing from 12 to 20 grains.

They burn with a paler flame, and require less oxygen than olefiant gas for perfect combustion.

430. It has generally been stated that these gases contain a definite compound of 1 proportional of carbon and 2 of hydrogen, to which the term *bi-hydroguret of carbon*, or *light hydrocarbonate*, has been applied. From many experiments, however, on this subject, I am induced to consider them as mixtures of olefiant gas and hydrogen, since I have never

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* The sp. gr. (according to Thomson) is to oxygen as 0.5 : 1; now 0.5 × 2 = 1 (atom); also 1 is just 8 times (0.125) the atom of hydrogen, 8 also represents its sp. gr. when hydrogen is taken = 1.

been able to obtain any other definite compound of carbon and hydrogen, than olefiant gas; and since they may be imitated by mixtures of olefiant and hydrogen gases, of the same specific gravities*.

Coal gas.

431. These mixtures are abundantly produced during the destructive distillation of common pit-coal; and the gas thus obtained is employed for the purposes of illumination, as an economical substitute for tallow, oil, &c. This process is carried on upon a very extensive scale in London, in several public and many private establishments. The coal is placed in oblong cast-iron cylinders, or *retorts*, which are ranged in furnaces, to keep them at a red heat, and all the volatile products are conveyed by a common tube into a *condensing vessel*, kept cold by immersion in water; and in which the water, tar, ammoniacal, and other condensible vapours, are retained; the gaseous products consist principally of carburetted hydrogen, sulphuretted hydrogen, and carbonic oxide, and acid: these are passed through a mixture of quicklime and water in vessels called *purifiers*, by which the sulphuretted hydrogen and carbonic gases are absorbed, and the carburetted hydrogen and hydrogen gases, transmitted sufficiently pure for use into *gasometers*, whence the pipes issue for the supply of streets, houses, &c. The coke remaining in the retorts is of a very good quality†.

432. The average specific gravity of purified coal-gas is 0.4500. 100 cubical inches weigh from 14 to 15 grains, and it may be considered as a mixture of about 55 volumes of hydrogen, and 45 of olefiant gas.

433. The best kind of coal for distillation is that which contains most bitumen and least sulphur. The chaldron should yield about 12000 cubical feet of purified gas, of which each Argand's burner, equal to six wax candles, may be considered as consuming from four to five cubical feet per hour.

434. The economy of gas illumination may be judged of by examining the value of the products of distillation of a chaldron of coals, the average cost of which may be considered as 3*l*. It should afford—

1 ¼	Chaldron of coke, at 25*s*.	1	11	3
24	Gallons of tar and ammoniacal liquor, at 3*d*. ..	0	6	0
12000	Cueic feet of gas, at 15*s*. per 1000 C.F	9	0	0
		£10	17	3

These products are taken at their lowest value, but they afford ample grounds for showing the advantage of gas illumination, not merely for public purposes, but also in private establishments. It appears that where more than fifty lights are required, a coal-gas apparatus will be found profitable.

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* Thomson gives the specific gravity of bihydroguret of carbon or carburetted hydrogen, =0.555, which at a mean temperature makes 100 c. i. weigh 16.99 grains—its composition is also given.

Carbon .... 0.416 .... =(1 vol.)
Hydrogen ...... 0.0694 × 2 .... =(2 vols.)

† Mr. Parker, of Liverpool, (*Phil. Mag*. Vol. lii. p. 292,) has proposed to pass the gas as it comes from the coal retorts through red-hot iron tubes, by which the contaminating gases and vapours are further decomposed, and the quantity of useful gas much increased. This suggestion, if it succeeded, would greatly diminish the quantity of tar, which is the only useless product; but as carburetted hydrogen is decomposed at a red heat, it will obviously tend to diminish the illuminating power of the gas, though it will increase its quantity.

Oil gas. 435. Messrs. J. and P. Taylor have lately constructed an apparatus for the conversion of oil into gas. It consists of a furnace with a contorted iron tube containing fragments of brick or coke, passing through it, into which, when red-hot, the oil is suffered to drop; it is decomposed, and converted almost entirely into charcoal, which is deposited in the tube, and into a mixture of carburetted hydrogen, and hydrogen gases, of which from two to three cubic feet may be regarded as equivalent to five or six of coal-gas, for the production of light.—*Quarterly Journal*, Vol. viii.

The commonest whale-oil, or even pilchard-dregs, quite unfit for burning in the usual way, afford abundance of excellent gas. requiring no other purification than passing through a refrigerator, to free it of a quantity of empyreumatic vapour.

436. A gallon of whale-oil affords about 100 cubical feet of gas, and an Argand burner, equal to seven candles, consumes a cubical foot and a half per hour. The cost of a lamp fed by oil or coal gas, and giving the light of seven candles will be 3 farthings per hour.
Of Argand's lamp with spermaceti oil 3*d*.
Mould-candles 3½
Wax-candles 14

437 By a series of experiments, conducted with every requisite caution (*Phil. Trans*. 1820, p .23,) I found that, to produce the light of ten wax candles for one hour, there were required

2600 cubical inches of pure carburetted hydrogen or olefiant gas.
4875 . . . . oil gas.
13120 . . . . coal gas.

438. The fitness of the gas obtained from coal for the purposes of illumination, is, *ceteris paribus*, dependent upon the quantity of carburetted hydrogen, or olefiant gas, which it contains; and, consequently, the fitness of the purified mixed gas for illumination, will be directly as its specific gravity; or, the relative proportion of olefiant gas may be judged of by mixing the purified coal gas with twice its volume of chlorine over water, by which the olefiant gas will be absorbed, and its quantity shown by the amount of the absorption which takes place.

439. Experiments, thus conducted, show that purified *coal gas* seldom contains more than 40 *per cent*. in volume of carburetted hydrogen, while *oil gas* generally affords about 75 *per cent*.; hence its superiority for burning, and the relatively small quantity consumed.

Dr. Henry (*Phil. Trans*. 1808,) has given some important experiments upon the production of gas from coal, by which it appears that its composition is very various at different stages of the distillation. The mode of distillation also affects the quantity and quality of the products.

440. An account of the apparatus for the production of coal gas, and of its construction and expense, will be found in the *Treatises on Gas Lights*, by Mr. Accum and Mr. Peckston.

Safety lamp. 441. A mixture of carburetted hydrogen and hydrogen is contained abundantly in coal strata, from fissures in which it is sometimes evolved in large quantities, forming what in the language of the north country miners, is called a *blower*. When this gas has accumulated in any part of the gallery or chamber of a mine, so as to be mixed in certain proportions with common air, the presence of a lighted candle, or lamp, causes it to explode, and to destroy, injure, or burn, whatever is exposed to its violence. The miners are either immediately killed by the explosion, and thrown, with the horses and machinery, through the shaft into the air, the mine becoming as it were an enormous piece of artillery from which they are projected; or they are gradually suffocated, and undergo a more painful death from the carbonic acid and nitrogen remaining in the mine, after the explosion of the *fire damp;* or what, though it appears the mildest, is perhaps the most severe fate, they are burned or maimed, and often rendered incapable of labour and of healthy enjoyment for life.—DAVY, *on the Safety-Lamp for Coal Miners*, London, 1818.

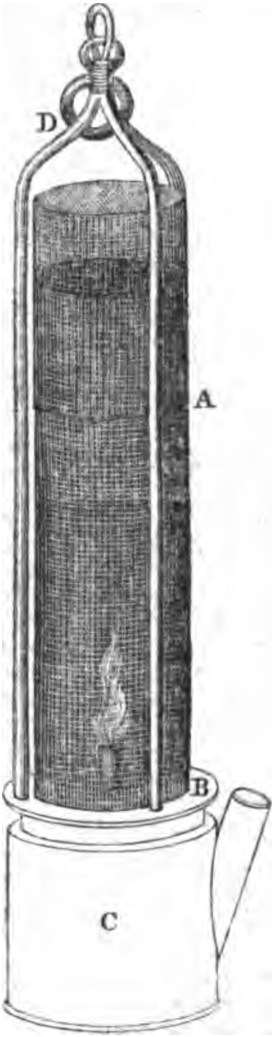
Sir H. DAVY, in the treatise just quoted, has given a sketch of different, but ineffectual, contrivances of others, for the prevention of these dreadful, and hitherto frequently occurring, accidents; and has described the train of investigation by which he was led to the discovery of a remedy at once simple and efficient, and which has already been submitted to repeated and successful trials.

442. The properties of flame, and the principle of safety adopted in this lamp, have already been adverted to (192). It is obvious, from what has there been said, that if the flame of a common lamp be every where properly surrounded with wire-gauze, and in that state immersed into an explosive gaseous mixture, it will be inadequate to its inflammation, that part only being burned which is *within* the cage, communication to the inflammable air *without* being prevented by the cooling power of the metallic tissue; so that by such a lamp the explosive mixture will be consumed, but cannot be exploded.

443. The following wood cut is a representation of the Safety lamp, as recommended for general use by Sir H. Davy. A is a cylinder of wire-gauze, with a double top, securely and carefully fastened, by doubling over, to the brass rim B, which screws on to the lamp C. The whole is protected and rendered convenient for carrying, by the frame and ring D. If the cylinder be of twilled wire-gauze, the wire should be at least of the thickness of one-fortieth of an inch, and of iron or copper, and 30 in the warp, and 16 or 18 in the weft. If of plain wire gauze, the wire should not be less than one-sixtieth of an inch in thickness, and from 28 to 30 both warp and woof.—DAVY, *on the Safety Lamp*, p. 114, *et seq.*

The operation of this lamp may be shown on a small scale by suspending it in a glass jar, and then admitting a sufficient stream of coal gas to render the enclosed atmosphere explosive. The flame of the lamp first enlarges, and is then extinguished, the whole of the cage being filled with a lambent blue light; on turning off the supply of gas this appearance gradually ceases, and the wick becomes rekindled, when the atmosphere returns to its natural state.

As the *safety* of these lamps entirely depends upon the perfect state of the wire gauze, and upon the non-existence of any aperture or channel sufficiently large to admit of the passage of flame, they should, when in use in a coal mine, beinspected daily to ensure their soundness in these respects.



444. The analysis of a mixture of hydrogen with carburetted hydrogen, carbonic oxide, and carbonic acid, presents peculiar difficulties in the ordinary mode of proceeding; and as it often requires to be performed in investigations relating to the gases used for illumination, it became an object to facilitate the process, for which I have used the following plan:

A hundred measures of the gas are introduced into a graduated tube, and the carbonic acid absorbed by a solution of potassa; the remaining gas is then transferred to thrice its volume of chlorine of known purity, standing over water in a tube of about half an inch diameter, and exposed to daylight, but carefully excluded from the direct solar rays; after 24 hours the carburetted hydrogen and the excess of chlorine will have been absorbed, and the remaining gas, consisting of carbonic oxide and hydrogen, may be analyzed by detonation with oxygen in excess; the measure of carbonic acid formed being equal to that of the original carbonic oxide.

This proceeding depends upon the non-formation of chlorocarbonic (397) acid in a mixture of carbonic oxide and chlorine in the contact of water, and out of the direct agency of the solar rays. Such mixture I have kept several days occasionally renewing the chlorine as it became absorbed by the water, and have not observed any diminution in the bulk of the carbonic oxide. In all these cases it is necessary to ascertain the purity of the chlorine by its absorption by water, and to be aware of the evolution of common air from water during that process.

445. *Carbon and Nitrogen—Carburet of Nitrogen—Cyanogen.*—This gaseous compound was discovered in 1815, by Gay-Lussac (*Annales de Chimie*, xcv.) It may be obtained from dry and pure *cyanuret of mercury*. This substance when heated in a small glass tube to dull redness, becomes black, and a quantity of mercury passes over and condenses in the cold part of the tube: the gas which is at the same time evolved, must be collected over mercury. Union with nitrogen.

446. It has a penetrating and very peculiar smell, somewhat resembling that of bitter almonds; it burns with a beautiful purple flame. *Its specific gravity to hydrogen is 26. 100 cubic inches weighing 55. grains. Water dissolves 4.5 volumes, and alcohol 23 volumes of this gas.* The aqueous solution reddens vegetable blues; and according to Vauquelin (*Annales de Chim.*, Oct. 1818,) is subject to spontaneous decomposition, being gradually converted into carbonic and hydrocianic acids, ammonia, a peculiar acid, which he calls the *cyanic*, and a brown substance containing carbon; the ammonia saturates the acids, and the carbonaceous compound is deposited. These changes are referable to the mutual re-action of the elements of cyanogen upon those of water.

447. Cyanogen may be analyzed by detonation with oxygen. One volume, detonated over mercury with two of oxygen, produces two volumes of carbonic acid, and one of nitrogen. Whence it appears that cyanogen consists of two proportionals of carbon = 12. and 1 of nitrogen = 14, the nitrogen having suffered no change of bulk by uniting with the carbon; or it may be said to consist of two volumes of gaseous carbon + one volume of nitrogen, the three being condensed into one volume. Its representative number is 26.

The following symbols exhibit the mixture of cyanogen with oxygen in the above proportions, and the result of their detonation:

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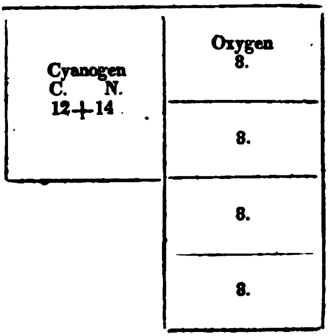
* Its specific gravity is to oxygen as 1.625 : 1; now 1.625 × 2 = 3.25 (its atom.): also, 3.25 is just 26 times (0.125) the atom of hydrogen.

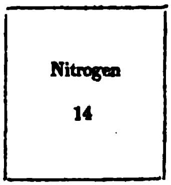
Before detonation.

One proportional of Cyanogen and four of Oxygen.

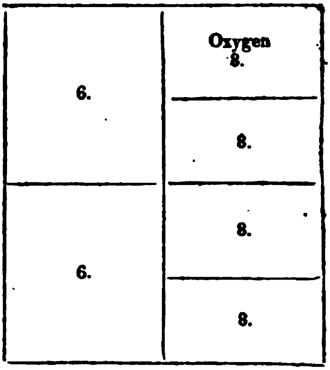


After detonation.

One proportional of Nitrogen.



Two proportionals of Carbonic Acid.

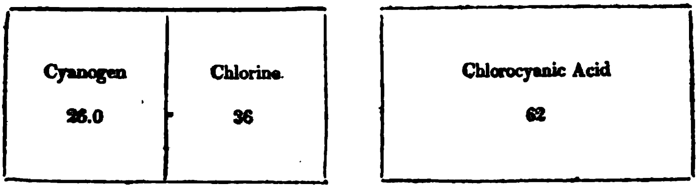


Union of cyanogen and chlorine.

448. *Cyanogen and Chlorine* combine and produce the *Chlorocyanic acid.* M. Gay-Lussac procured this compound by passing a current of chlorine through a solution of hydrocyanic acid (452) in water, till the liquid discoloured a diluted solution of indigo in sulphuric acid. He then deprived it of excess of chlorine by agitation with mercury. To separate chlorocyanic acid from this liquid, he took a glass cylinder, filled it two-thirds with mercury, and then to the brim with the above liquid, and inverted it in a basin of mercury. This basin and cylinder were put under the receiver of an air-pump, and the air drawn out, till the mercury and liquid were displaced; the cylinder became filled with the vapour of chlorocyanic acid; on admitting the air, the vapour condensed into a liquid, and the mercury rose in the cylinder. It may also be obtained by carefully distilling the liquid into a receiver surrounded by ice.

449. Chlorocyanic acid thus obtained is a colourless and very volatile liquid, having a peculiar and irritating odour. It reddens litmus; is not inflammable; and does not form detonating mixtures either with oxygen or hydrogen.

450. It appears from the researches of Gay-Lussac, that this acid, in its pure and gaseous state, consists of 1 proportional of dyanogen + 1 proportional of chlorine, or 26 + 36 = 62. The gases by combination suffer no change of volume; hence the following symbols represent its composition and volume.—*Annales de Chimie*, xcv. 205.



451. *Iodine and Cyanogen* form a volatile solid compound, which collects in flocculi, and has an acrid taste and pungent smell; it may be formed by heating iodine with cyanuret of mercury.—DAVY, *Quart. Journ.* i. 289. Union of cyanogen and iodine.

452. *Cyanogen and Hydrogen—Hydrocyanic* or *Prussic acid.*—This triple compound may be obtained by moistening cyanuret of mercury with muriatic acid, and distilling at a low temperature, having surrounded the receiver with ice. Union of cyanogen and hydrogen.

453. A liquid is thus obtained which has a strong pungent odour, very like that of bitter almonds; its taste is acrid, and it is highly poisonous. It volatilizes so rapidly as to freeze itself. It reddens litmus. The specific gravity of its vapour, compared with hydrogen, is 13.5, so that 100 cubic inches weigh 28.579 grains; detonated with oxygen it gives as results one volume of carbonic acid gas, half a volume of hydrogen, and half a volume of nitrogen; so that it consists of 1 volume of cyanogen + 1 volume of hydrogen, and its representative number is 27.

454. The hydrocyanic acid is used in medicine, and several formulæ have been given for its preparation: the following affords the acid of a convenient strength, and is that which is adopted at Apothecaries' Hall. One pound of cyanuret of mercury is put into a tubulated retort with six pints of water, and one pound of muriatic acid, specific gravity 1.15; a capacious receiver is luted to the retort, and six pints are distilled over. The specific gravity of the product is 0.995. As this acid in its dilute state suffers partial decomposition by keeping, it should be prepared in small quantities only for pharmaceutical use and preserved in vessels excluded from light.

455. It appears from the experiments of Mr. Porrett (*Phil. Trans.* 1814,) and from those of M. Gay-Lussac (*Ann. de Chim.* xcv.) that cyanogen is capable of forming a compound with sulphuretted hydrogen. It may be obtained by mixing one volume of cyanogen with one and a half of sulphuretted hydrogen; they slowly combine, and form a yellow crystallized compound.

456. According to Dr. Thomson, Mr. Porrett obtained an analogous body by a much more circuitous process; he has termed it *sulphuretted chyazic acid;* and Dr. Thomson, who regards it as consisting of cyanogen and sulphur only, calls it *Sulphocyanic acid.*—*Syst.* V. ii. p. 290. He describes it as soluble in water; of a smell resembling vinegar; and decomposed by repeated distillation.

457. The compound described by Gay-Lussac consists of two proportionals of cyanogen, three of sulphur, and three of hydrogen ; Dr. Thomson considers it as containing two of cyanogen and three of sulphur ; this would give as its ultimate constituents,

4	Proportionals of carbon	22.8
2	of nitrogen	26.0
3	of sulphur	45.0
		93.8*

458. Sir H. Davy has noticed the production of a compound of sulphur and cyanogen, obtained by heating a mixture of sulphur and cyanuret of mercury ; and by heating phosphorus with cyanuret of mercury, a *cyanuret of phosphorus* appears to be formed.

Union with sulphur.

459. *Carbon and Sulphur—Sulphuret of Carbon.* This is a liquid obtained by passing sulphur over red-hot charcoal. When purified by re-distillation, it is transparent, colourless, and insoluble in water, but soluble in alcohol and ether ; its refractive power in regard to light is very considerable. Its specific gravity is 1.272. It boils at 106°, and does not freeze at—60°. It is very volatile, and has a pungent taste and peculiar fetid odour. The cold which it produces during evaporation is so intense, that by exposing a thermometer bulb, covered with fine lint, and moistened with it, in the receiver of an air-pump, the temperature sunk, after exhaustion to — 80°. When a mercurial thermometer was used, the metal froze.

460. Sulphuret of carbon is inflammable, and when burned with oxygen, produces sulphurous and carbonic acids. It consists of 1 proportional of charcoal and 2 of sulphur ; $6 + 32 = 38$. (BERZELIUS and MARCET, *Phil. Trans.* 1813). It was discovered by Lampadius, who called it *Alcohol of Sulphur.*—CRELL's *Annals*, 1796, ii.

461. A portion of carburet of sulphur appears to be frequently formed during the production of inflammable gas from coal (431), and to be retained in the state of vapour by the gas after its purification by lime ; such gas gives a strong sulphurous smell when burned, although perfectly cleansed from sulphuretted hydrogen.—BRANDE, *Phil. Trans.* 1820, p. 19.

Union with phosphorus.

462. *Carbon and Phosphorus—Phosphuret of Carbon.*—To obtain this compound, Dr. Thomson directs the following process : (*System* i. p. 276.) Allow phosphuret of lime to remain in water, till it no longer evolves gas ; then add to the liquid excess of muriatic acid, agitate for a few moments, and throw the whole upon a filter. Phosphuret of carbon remains, which is to be washed and dried. This compound is a soft powder, of a yellowish colour, without taste or smell ; exposed to air, it slowly imbibes moisture, and acquires an acid flavour. Exposed to a red heat, it burns, and gradually gives out its phosphorus, the charcoal being prevented burning by a coating of phosphoric acid. It consists of phosphorus 0.62 + carbon 0.38 (THOMSON's *Annals*. viii. 157.) These numbers closely correspond with

Phosphorus	1	proportional .... =	12
Carbon	1	ditto.	6
			18

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* The substance described by Mr. Porrett is evidently distinct from that mentioned by Gay-Lussac, which is not sour. But the nature of these compounds is as yet imperfectly understood.

It would appear from the mode of of obtaining this phosphuret, that it forms an ingredient in phosphuret of lime, as usually prepared.

SECTION VI. *Boron.*

Mode of obtaining.

463. THIS substance is obtained by heating in a copper tube two parts of the metal called potassium, with one of boracic acid previously fused and powdered. In this experiment the boracic acid, which consists of boron and oxygen, is decomposed by the potassium. The fused matter is washed out of the tube with water, and the whole put upon a filter. The boron remains in the form of a brown insipid insoluble powder, unaltered by exposure to air at common temperatures, but when heated to 600° it burns with much brilliancy, especially in oxygen gas, and produces *boracic acid*. It is a non-conductor of electricity.

464. Boracic acid is usually obtained by dissolving the salt called *borax* in hot water, and subsequently adding half its weight of sulphuric acid; as the solution cools, white scaly crystals appear, which, when washed with cold water are nearly tasteless, and which consist of boracic acid combined with water, and retaining a little sulphuric acid, which it loses by exposure to a strong red heat, and fuses into a glass.

Boracic acid is very difficultly soluble in water; the solution reddens vegetable blues, but possesses the singular property of rendering the yellow of turmeric brown, in the manner of an alkali. Its solution in spirit of wine burns with a green flame. This acid was first obtained by Homberg, in 1702, and was used in medicine, under the name of *Homberg's Sedative Salt.* Its nature was first shown by Davy, in 1807.

465. The experiments upon the composition of boracic acid are much at variance. Berzelius's determination probably approaches nearest to truth: he regards it as containing 1 boron + 3 oxygen (THOMSON'S *System*, Vol. i. p. 249, 5th edit.) If, therefore, we consider it as consisting of 1 proportional of boron and 2 of oxygen, the number representing boron will be 5, and boracic acid will consist of

1 Boron.	5.28
3 Oxygen.	16
Boraic acid.	21.28

466. *Native boracic acid* has been found in the Lipari islands, and also in the hot springs of Sasso, in the Florentine territory; hence the term *Sassolin* applied to it by some mineralogists.

467. The boracic acid forms, with ammonia, a *Borate of ammonia*, composed according to Berzelius (*Annals of Philosophy*, iii. 57,) of

37.95	Acid
30.32	Ammonia.
31.73	Water.

468. Boron burns in chlorine, but the chloride has not been examinned, nor have its other compounds been investigated.

APPENDIX.

ENGLISH WEIGHTS AND MEASURES.

469. The English *troy* pound is subdivided into twelve ounces, and each ounce is equal to 480 grains. The subdivisions of the troy ounce, called *Apothecaries weight*, are into 8 drachms, each drachm into 3 scruples, and each scruple into 20 grains. The troy ounce is also sometimes divided into 20 penny weights, of 24 grains each. These are the weights generally employed by chemists, but for philosophical purposes ambiguity is most easily avoided by employing the grain as integer: and the laboratory should be provided with good sets of weights, from one thousand grains downwards; the grain should be decimally subdivided into tenths and hundredths.

470. The standard of most articles bought and sold in common life is the *avoirdupois* pound, which is equal to 7000 troy grains, and is divided into 16 ounces, of 437.5 troy grains each. The avoirdupois ounce is legally divided into 16 drachms, of 27.34375 grains each; but this division is rejected in all ordinary cases, in consequence of the confusion likely to result between the troy and avoirdupois drachm, so that the term *drachm* is almost exclusively employed to denote the eighth part of a troy ounce, or 60 grains.

471. For measures of capacity, the *wine pint* is usually employed, which corresponds to 28.875 cubical inches of water, at a temperature of 60°. It is subdivided into 16 ounces; the ounce into 8 drachms. Two pints make a quart, and 4 quarts a gallon.

472. The *ale pint* contains 35.25 cubical inches of water, at 60°.

473. For chemical use the most convenient measure is the bulk occupied by the troy ounce of distilled water, which may be subdivided into 480 grains, and which is equal to 1.8047 cubical inches.

474. The length of the pendulum, vibrating seconds, *in vacuo*, in the latitude of London (51° 31′ 8″.4 North at the level of the sea, and at the temperature of 62°, is = 32.13929 inches of Sir George Shuckburg's standard scale.—Kater, *Phil. Trans.* 1819, p. 415.

475. In the following Tables are shown the subdivisions of the English troy and avoirdupois pounds, and of the English wine gallon, and their correspondence with the French *gramme* and *litre*.

ENGLISH WEIGHTS AND MEASURES.

476. Troy Weight.

Pound.	Ounces.	Drms.	Scruples.	Grains.	Grammes.
1	12	96	288	5760	372.96
	1	8	24	480	31.08
		1	3	60	3.885
			1	20	1.295
				1	0.06475

477. Avoirdupois Weight.

Pound.	Ounces.	Drms.	Grains.	Grammes.
1	16	256	7000	453.25
	1	16	437.5	28.328
		1	27.34375	1.7705

478. Wine Measure.

Gal.	Pints.	Ounces.	Drms.	Cub. Inch.	Litres.
1	8	128	1024	231	3.78515
	1	16	128	28.875	0.47398
		1	8	1.8047	0.02957
			1	0.2256	0.00396

FRENCH WEIGHTS AND MEASURES.

479. The French metrical system is founded on a single standard of length, called a *metre*, and which is equivalent to the ten millionth part of the arc of the meridian, extending from the equator to the pole. The length of the metre, at the temperature of 32°, as ascertained by Captain Kater (*Phil. Trans.* 1818,) is 39.37079 English inches.

480. The French measures increase and decrease in decimal proportions, a distinctive prefix being put to the term by which the integer is called. These prefixes are *deca*, *hecto*, *kilo*, and *myria*, taken from the Greek numerals, to express the *multiplication* of the integer by 10, 100, 1000, and 10000 respectively: and *deci*, *centi*, and *milli*, from the Latin numerals, to express the division of the integer by 10, 100, or 1000; as in the following Table:

	Metres.		Metre.
1 Myriametre	10000	1 Metre	1
1 Kilometre	1000	1 Decimetre	0.1
1 Hectometre	100	1 Centimetre	0.01
1 Decametre	10	1 Millimetre	0.001

481. The metre is the integer of the measure of length, and from it all measures of surface, capacity, and weight, are deduced as follows.

For square dimensions, the metre, or its parts squared, are employed. When used for measuring land the term *are* is adopted, which is a decametre squared. A *hectare*, or 100 *ares*, is about equal to 2 English acres.

For the integer of the measure of capacity, the cubed decimetre is employed, under the name of *litre*, which is about equal to 2¼ English wine pints.

For the integer of the measure of weight, the weight of a cubic centimetre of distilled water, at 32°, has been adopted: it is called a *gramme*, and is equal to 15.4 English grains.

482. The following are the principal Tables of French Weights and Measures, which will be found useful in the laboratory. In *Appendix* II. of Aikin's *Dictionary*, the chemical reader will find several others showing the relation of the French to the English standards:

FRENCH WEIGHTS AND MEASURES.

483.—MEASURES OF LENGTH.

		English Inches.		Mil.	Fur.	Yds.	Feet.	In.
Millimetre	=	.03937						
Centimetre	=	.39371						
Decimetre	=	3.93710						
Metre	=	39.37100						
Decametre	=	393.71000	=	0	0	10	2	9.7
Hecatometre	=	3937.10000	=	0	0	109	1	1
Kilometre	=	39371.00000	=	0	4	213	1	10.2
Myriometre	=	393710.00000	=	6	1	156	0	6

484.—MEASURES OF CAPACITY.

		Cubic Inches.		English.			
				Tons.	Hogs.	Wine G.	Pints.
Millilitre	=	.06103					
Centilitre	=	.61028					
Decilitre	=	6.10280					
Litre	=	61.02800	=	0	0	0.	2.1133
Decalitre	=	610.28000	=	0	0	2.	5.1352
Hecatolitre	=	6102.80000	=	0	0	26.419	
Kilolitre	=	61028.00000	=	1	0	12.19	
Myriolitre	=	610280.00000	=	10	1	58.9	

485.—MEASURES OF WEIGHT.

		English grains.		Avoirdupois.		
				Poun.	Oun.	Dram.
Milligramme	=	.0154				
Centigramme	=	.1544				
Decigramme	=	1.5444				
Gramme	=	15.4440				
Decagramme	=	154.4402	=	0	0	5.65
Hecatogramme	=	1544.4023	=	0	3	8.5
Kilogramme	=	15444.0234	=	2	3	5
Myriogramme	=	154440.2344	=	22	1	2

TABLE OF THE SPECIFIC GRAVITY OF WATER, AT EVERY DEGREE OF TEMPERATURE, FROM 30° TO 80° FAHR.

486. The following Table is given by Mr. Gilpin, in the 84th volume of the *Philosophical Transactions*, and is of essential use for taking the specific gravities both of solids and fluids, by enabling the operator to reduce the weight or bulk of the distilled water, employed in any case, to that which it would have at any other common temperature, and particularly to 60°, which is the usual standard.

487. Thus, for example, since the specific gravity of water at 47° is 1.0008, and at 60° is 1.00000, and (consequently 10008 grains, at 47°, are equal in bulk to 10000 grains at 60°,) it follows that it would require 252.708 grains, at 47°, to equal the space of a cubic inch; for 10000 : 10008 :: 252.506, (the weight of a cubic inch at 60°,) : 252.708.

488. The remarkable anomaly of the specific gravity of water *decreasing* through all the degrees of temperature below 40°, or thereabouts, that it remains uncongealed, has been noticed under the article HEAT (60); but the difference for one or two degrees above or below 40° is so trifling, that it has hardly yet been ascertained with perfect accuracy.

489. TABLE OF THE SPECIFIC GRAVITY OF WATER.

AT EVERY DEGREE OF TEMPERATURE, FROM 30° TO 80° FAHR.

Fahr.	Specific Gr.	Fahr.	Specific Gr.
30°	1.00074	56°	1.00031
31	1.00078	57	1.00024
32	1.00082	58	1.00016
33	1.00085	59	1.00008
34	1.00088	60	1.00000
35	1.00090	61	0.99991
36	1.00092	62	0.99981
37	1.00093	63	0.99971
38	1.00094	64	0.99961
39	1.00094	65	0.99950
40	1.00094	66	0.99939
41	1.00093	67	0.99928
42	1.00092	68	0.99917
43	1.00090	69	0.99906
44	1.00088	70	0.99894
45	1.00086	71	0.99882
46	1.00083	72	0.99869
47	1.00080	73	0.99856
48	1.00076	74	0.99843
49	1.00072	75	0.99830
50	1.00068	76	0.99816
51	1.00063	77	0.99802
52	1.00057	78	0.99788
53	1.00051	79	0.99774
54	1.00045	80	0.99759
55	1.00038		

TABULAR VIEW OF SPECIFIC GRAVITIES, REPRESENTATIVE OF EUQUIVALENT NUMBERS, &c.

490. The following Table shows, at one view, the specific gravities of the simple substances described in this volume, and of their mutual combinations; it also exhibits their equivalent numbers, and the proportions in which they combine.

TABULAR VIEW OF THE SPECIFIC GRAVITIES, AND EQUIVALENT NUMBERS OF THE SUPPORTERS OF COMBUSTION AND ACIDIFIABLE SUBSTANCES AND OF THE COMPOUNDS WHICH THEY FORM WITH EACH OTHER.

SUBSTANCES.	100 Cubic Inches weigh grs.	Specific Gravity compared to			Equivalent Number	COMPOSITION
		Hydrogen	Air.	Water		
491. I. OXYGEN	33.88	16	1.1111		8	
492. II. CHLORINE	76.25	36.	2.5		36	
Oxide of Chlorine	76.25	31.75	.444444		68.	32 oxy. + 36 chl.
Chloric acid					76	40 oxy. + 36 chl.
Oxychloric acid					92	56. oxy. + 36. chl.
493. III. IODINE (vapour of)	264.625	125	8.6805	4.948	125	
Oxiodic acid					165.	40 oxy. + 125 iodine.
Chloriodic acid					161.	36 chl. + 125 iodine.
494. I. HYDROGEN	2.117	1	.0694		1	
Water	25295.3	11242.3	837.55	1	9.0	8 oxy. + 1 hy.

Supporters of Combustion and Acidifiable Substances (continued.)

SUBSTANCES	100 Cubic Inches weigh grs.	Specific Gravity compared to Hydrogen	Specific Gravity compared to Air	Specific Gravity compared to Water	Equivalent Number	COMPOSITION
Steam	19.05	9.	0.625	1343.3		
Muriatic acid gas	39.162	18.5	1.2851		37.	36 chl. + 1 hy.
——— solution				1.21		480 vol. of gas.
Hydriodic acid	133.37	63	4.375		126.	125 iode + 1 hy.
495. II. NITROGEN	29.625	14	.9721		14	
Nitrous oxide	46.574	22.	1.52725		22.	14 nit. + 8. oxy.
Nitric oxide	31.755	15	1.0428		30	14 nit. + 16 oxy.
Nitrous acid	48.69	23.	2.13566		46	14 nit. + 32 oxy.
Nitric acid (dry)					54.	14 nit. + 40 oxy.
Nitric acid (liquid)				1.5	72.	54. nit. ac. + 18 w.
Chloride of nitrogen				1.6	158	14 n. + 144 chlo.
Common air	30.5	14.4	1			21 oxy. + 79 n.

Supporters of Combustion and Acidifiable Substances (continued.)

SUBSTANCES	100 Cubic Inches weigh grs.	Specific Gravity compared to			Equivalent Number	COMPOSITION.
		Hydrogen	Air	Water		
Iodide of nitrogen						
Ammonia	18.	8.5	.596	....	17.	14 n. + 3 hy.
——— solution	....	....	....	.875		670 volumes.
Chlorate of ammonia	....		....	....	93	76 chl. ac. + 17 am.
Iodate of ammonia						
Muriate of ammonia	....		....	1.45	54.	17 am. + 37. m. a.
Hydriodate of ammonia	....		....	....	143.	17 am. + 126 hy. a.
Nitrate of ammonia	....		....	1.5785	71	17 am. + 54 n. a.
Atmospheric air						
496. III. SULPHUR	....			1.99	16	
Hyposulphurous acid					24.	16 sul. + 8 oxy.
Hyposulphite of ammonia					41.	17 am. + 24 hyposul. a.
Sulphurous acid	67.5	30	2.235	....	32	16 sul. + 16 oxy.

Supporters of Combustion and Acidifiable Substances (continued.)

SUBSTANCES	100 Cubic Inches weigh grs.	Specific Gravity compared to			Equivalent Number	COMPOSITION
		Hydrogen	Air	Water		
Sulphite of ammonia		....	....	....	81	17 am. + 64 sul. acid.
Hypo-sulphuric acid						
Sulphuric acid (dry)	....	....	....	....	40	16 sul. + 24 oxy.
Sulphuric acid (liquid)	....	....	....	1.9	49	40 s. a. + 9 water.
Sulphate of ammonia	....	....	....	....	57.	40 s. a. + 17 am.
Chloride of sulphur	....	....	....	1.6	52.	16 sul. + 36 chl.
Iodide of sulphur						
Sulphuretted hydrogen	36	17	1.92	....	17	16 sul. + 1 hy.
Hydrosulphuret of ammonia	....	....	....	....	51	34 s. h. + 17 am.
497. IV. PHOSPHORUS	....	....	....	1.77	12	
Oxide of phosphorus						
Hypophosphorous acid	....	....	....	....	32	24 P. + 8 oxy.

Supporters of Combustion and Acidifiable Substances (continued.)

SUBSTANCES	100 Cubic Inches weigh grs.	Specific Gravity compared to			Equivalent Number	COMPOSITION
		Hydrogen	Air	Water		
Hypophosphite of ammonia						
Phosphorous acid					20	12 P.+8 oxy.
Hydrophosphorous acid					49	40 P. a.+9. water.
Phosphite of ammonia					37.	20 P. a. +17 am.
Phosphoric acid				2.85	28	12 P.+16 oxy.
Phosphate of ammonia					45	28 P. a. +17 am.
Chloride of phosphorus				1.45	48	12 P. +36 chl.
Perchloride of phosphorus					84	12 P.+72 chl.
Iodide of phosphorus						
Hydro-phosphoric gas	29.645	14	.9685		14	P. 12+hy. 2.
Phosphuretted hydrogen	27.527	13	.894		13	P. 12+hy. 1.
Sulphuret of phosphrous					40	P. 24+sul. 16.

Supporters of Combustion and Acidifiable Substances (continued.)

SUBSTANCES	100 Cubic Inches weigh grs.	Specific Gravity compared to			Equivalent Number	COMPOSITION
		Hydrogen	Air	Water		
498. V. CARBON (Diamond)	....	....	....	3.5	6.	
Carbonic oxide	29.63	14	.9834	....	14	Carb. 6 + oxy. 8.
Chlorocarbonic acid	105.85	50	3.47915	....	50	C. Ox. 14 + chl. 36.
Carbonic acid	46.464	22	1.54215	....	22	Carb. 6 + oxy. 16.
Carbonate of ammonia	....	....	....	....	39	C. a. 22 + am. 17.
Sesquicarbonate of ammonia						
Bicarbonate of ammonia	....	....	....	....	61	C. a. 44 + am. 17.
Protochloride of carbon	....	....	....	1.55	42	Carb. 6 + chl. 36.
Perchloride of carbon	....	....	....	2.	....	Carb. 12 + chl. 102.
Carburetted hydrogen (olefiant)	30.15	13.4	.9983	....	7	Carb. 6. + hy. 1.
Hydrochloride of carbon	....	....	....	1.2201	50	Olef. 14 + chl. 36.
Hydriodide of carbon						
Cyanogen	.55	26	1.8178	....	26.	Carb. 12. + n. 14

Supporters of Combustion and Acidifiable Substances (continued.)

SUBSTANCES	100 Cubic Inches weigh grs.	Specific Gravity compared to			Equivalent Number	COMPOSITION
		Hydrogen	Air	Water		
Chloro-cyanic acid	65.1375	31	2.152775	....	62.	Cy. 26 + ch. 36.
Hydro-cyanic acid	28.579	13.5	.94615	....	27.	Carb. 12. + nit. 14 + hy. 1.
Hydro-cyanate of ammonia						
Sulphocyanic acid						
Sulphuret of carbon	....	....	....	1.272	38	Carb. 6 + sul. 32.
Phosphuret of carbon						
499. VI. BORON	....	....	....	....	6.	
Boracic acid	....	....	....	1.803	22	B. 6. + oxy. 16
Hydro-boracic acid	....	....	....	1.479	39	B. a. 22. + w. 17.
Borate of ammonia (crystallized)	....	....	....	....	57	B. a. 22. + am. 17. + w. 18.

TABLE SHOWING THE CONNEXION BETWEEN THE

ATOMS OF GASES AND THEIR SPECIFIC GRAVITIES.

(Deduced from Thomson's paper in the annals of Philos. Vol. 16, for the year 1820.)

GASES.	Atom of hydrogen that of oxygen being = 1.		Specific gravities compared with hydrogen.		Specific gravities compared with oxygen.		Multiples.		Atoms compared with oxygen.
Chlorine	0.125	×	36	=	2.2500	×	2	=	4.500
Hydrogen	0.125	×	1	=	0.0625	×	2	=	0.125
Nitrogen	0.125	×	14	=	0.8750	×	2	=	1.750
Steam	0.125	×	9	=	0.5625	×	2	=	1.125
Protoxide of nitrogen . .	0.125	×	22	=	1.3750	×	2	=	2.750
Iodine vapour	0.125	×	125	=	7.8125	×	2	=	15.225
Sulphur vapour	0.125	×	16	=	1.0000	×	2	=	2.000
Sulphurous acid	0.125	×	32	=	2.0000	×	2	=	4.000
Sulphuretted hydrogen . .	0.125	×	17	=	1.0625	×	2	=	2.125
Phosphorus vapour	0.125	×	12	=	0.7500	×	2	=	1.500
Phosphuretted hydrogen .	0.125	×	13	=	0.8125	×	2	=	1.625
Bihydroguret of Phosphorus	0.125	×	14	=	0.8750	×	2	=	1.750
Carbon vapour	0.125	×	6	=	0.3750	×	2	=	0.750
Carbonic oxide . . . ,	0.125	×	14	=	0.8750	×	2	=	1.750
Chloro carbonic acid . .	0.125	×	50	=	3.1250	×	2	=	6.250
Carbonic acid	0.125	×	22	=	1.3750	×	2	=	2.750
Olefiant gas	0.125	×	14	=	0.8750	×	2	=	1.750
Carburetted hydrogen . .	0.125	×	8	=	0.5000	×	2	=	1.000
Carburet of nitrogen . .	0.125	×	26	=	1.6250	×	2	=	3.250

Note. From the above it will be seen, that all the gases there mentioned, have their atoms just *double* their specific gravities, when oxygen is taken as the standard for both; further, that every atom is exactly a multiple by a *whole number* of the atom denoting Hydrogen, and that this whole number, is always the *number of times* which each gas weighs an equal bulk of hydrogen; or, in other words, its specific gravity when compared with hydrogen. The following few gases are exceptions to the foregoing laws though, they also, follow a regular order.

GASES.	Atom of hydrogen (oxygen) = 1.		Sp. gr. compared with hydrogen.		Sp. gr. compared with oxygen.		Multiples.		Atoms compared with oxygen.
Oxygen	0.125	×	8(½)	=	1	×	1	=	1.000
Ammonia	0.125	×	17.(twice)	=	0.53125	×	4	=	2.125
Deutoxide of nitrogen . .	0.125	×	30.(twice)	=	0.9375	×	4	=	3.750
Muriatic acid gas	0.125	×	37.(twice)	=	1.1560	×	4	=	4.625
Hydriotic acid	0.125	×	126.(twice)	=	3.9375	×	4	=	15.750
Nitrous acid gas	0.125	×	30.(twice)	=	0.9375	×	4	=	3.750
Protoxide of chlorine . .	disagrees with the rest								

Note. The brackets contain the proportions which the foregoing numbers under the 2nd column bear to their specific gravities when compared with hydrogen, thus 8 is ½ the specific gravity of oxygen, and 17 double that of ammonia. It will be seen that with one exception (oxygen) the numbers in the column of multiples of this table are, individually, double those in the same column of the first table; and further that (with the same exceptions) the multiple of the atom of hydrogen in this last table is just double the specific gravity; whereas, in the first, its multiple is, throughout, exactly the specific gravity.

CHAPTER V.

OF THE METALS, AND THEIR COMBINATIONS.

501. THE metals constitute a numerous and important class of simple substances; many of them were diligently examined by the older chemists, who have left us valuable information concerning them; many are of more recent discovery; and the existence of several others has been demonstrated within the last twenty years.

Number of metals.

The metals are forty-two in number.

1 Gold
2 Silver
3 Copper
4 Iron
5 Mercury
6 Tin
7 Lead
8 Zinc
9 Bismuth
10 Antimony
11 Arsenic
12 Cobalt
13 Platinum
14 Nickel
15 Manganese
16 Tungsten
17 Tellurium
18 Molybdenum
19 Uranium
20 Titanium
21 Chromium
22 Columbium
23 Palladium
24 Rhodium
25 Iridium
26 Osmium
27 Cerium
28 Potassium
29 Sodium
30 Lithium
31 Barium
32 Calcium
33 Strontium
34 Magnesium
35 Silicium
36 Alumium
37 Yttrium
38 Glucium
39 Zirconium
40 Thorinum
41 Selenium
42 Cadmium

502. Of these metals the first seven were known in very remote ages. The ancients designated them by the names of the planets, to which they were supposed to have some mysterious relation; and each was denoted by a particular symbol, representing both the metal and the planet.

Ancient symbols.

Gold was the Sun, and was thus represented ☉
Silver . . . Moon . . . . ☽
Mercury . . Mercury . . . . ☿
Copper . . . Venus . . . . ♀
Iron . . . . Mars . . . . ♂
Tin . . . . . Jupiter . . . . ♃
Lead . . . . Saturn . . . . ♄

Zinc was not known to the ancients, though they were probably acquainted with its ores, and with their property of forming brass when fused with copper. (PLINY, Lib. xxxiv. cap. 2 and 10.) The word *Zinc* first occurs in the writings of Paracelsus, who died in 1541. Bismuth is mentioned in the *Bermannus* of Agricola, written about 1530. Antimony was first obtained in its pure state by Basil Valentine towards the end of the 15th century. The process is described in his *Currus Triumphalis Antimonii.* Arsenic and Cobalt were discovered by Brandt in 1733, (*Acta Upsal.* 1733 and 1742); their ores were known at a much earlier period. Platinum was first recognised as a peculiar body in 1741, by Mr. Charles Wood, Assay-Master in Jamaica. (*Phil. Trans.* Vol. xliv.) In 1751, the distinctive characters of Nickel were shown by Cronstedt (*Stockholm Transactions*), and Manganese was obtained by Gahn in 1774. (BERGMAN'S *Opuscula*, Vol. ii.) Tungsten was discovered by M. M. Delhuyart in 1781. (*Mémoires de Toulouse*). Tellurium and Molybdenum by Muller and Hielm, in 1782. Uranium by Klaproth in 1789. Titanium by Mr. Gregor, in 1789. Chromium by Vauquelin, in 1797. (*Annales de Chimie*, Vol. xxv.) In 1802, Mr. Hatchett discovered Columbium. (*Phil. Trans.*) Palladium and Rhodium were discovered by Dr. Wollaston; and Iridium and Osmium by Mr. Tennant, all in 1803. (*Phil. Trans.*) Cerium was announced in 1804 by M. M. Hisinger and Berzelius. (GEHLEN'S *Journal*, ii.) Potassium and Sodium were discovered in 1807 by Sir H. Davy, whose experiments also led to the discovery of the metallic nature of the ten following bodies. Thorinum and Selenium were announced by Berzelius in 1815 and in 1817; and Mr. Stromeyer, of Gottingen, discovered Cadmium in 1818.

Times of discovery.

503. The circumstances under which metals are found in the earth, will be stated in the chapter of this work relating to geology. It may here be remarked, that they seldom occur in an uncombined state, but almost always united to other substances, as in the four following classes:—

Natural combinations.

i. *Native metals* are those which occur pure or alloyed, and have but a feeble attraction for oxygen; such as platinum, gold, silver, mercury, and copper.

—With simple supporters of combustion.

ii. *Metals combined with simple supporters of combustion.* The compounds belonging to this class are chiefly *native metallic oxides:* there are also a few native *chlorides*, but no iodides have hitherto been discovered. The *fluorides*, of which there are a few, may also be regarded as belonging to this class.

—With simple inflammables.

iii. *Metals combined with simple inflammables.* This class includes the *native metallic sulphurets*, a very numerous and important series of ores. One *native carburet* only is known, that of iron. There are no native hydrurets, phosphurets, nor borurets.

—with acids.

iv. *Metals in combination with acids—Metallic salts.* Of these the most common are the native *carbonates*, *sulphates*, and *phosphates*: there are a few native *borates*; and a few species belong also to this class in which the oxide is united to a *metallic acid*: such as the *native arseniates*, *chromates*, *tungstates*, and *molybdates*.

General characteristics.

504. The metals, as a class, are characterized by a peculiar lustre and perfect opacity: they are excellent conductors of heat, (74) and of electricity (102.)

505. There is the greatest difference in the specific gravity of the different metals, the heaviest and lightest solids being included in the list.

The principal metals, arranged according to their specific gravities, stand as follow :

Order of specific gravities.

1	Platinum	21.00
2	Gold	19.30
3	Tungsten	17.50
4	Mercury	13.50
5	Paladium	11.50
6	Lead	11.35
7	Silver	10.50
8	Bismuth	9.80
9	Uranium	9.00
10	Copper	8.90
11	Arsenic	8.35
12	Nickel	8.25
13	Cobalt	8.00
14	Iron	7.78
15	Molybdenum	7.40
16	Tin	7.30
17	Zinc	7.00
18	Manganese	6.85
19	Antimony	6.70
20	Tellurium	6.10
21	Sodium	0.972
22	Potassium	0.865

506. The specific gravity of solids and liquids is always expressed in numbers referring to water as = 1.

Method of determining specific gravity.

Of solids.

To ascertain the specific gravity of solids we employ a delicate balance, so contrived as to admit of substances being attached to one of the scales by means of a horse-hair or a fine thread of silk. The absolute weight of the body thus suspended is then very carefully ascertained : it is next immersed in distilled water, of the temperature of 60° ; and the beam being again brought to an equilibrium, we learn the weight lost by its immersion ; or, in other words, we ascertain the weight of its bulk of pure water. We now divide the sum of its absolute weight by that of the weight which it lost in water, and the quotient is its *specific weight*, or gravity, compared with water of the temperature of 60°.

Suppose a substance, weighing 360 grains, to lose 60 by immersion in water, the specific gravity of that substance will be = 6 ; for 360 ÷ 60 = 6.

Of fluids.

507. For ascertaining the specific gravity of liquids, we generally employ a thin phial, holding 1000 grains of distilled water, at the temperature of 60°. If filled with any other liquid, and weighed, we learn its specific gravity ; thus we should find that it would contain 13500 grains of mercury ; 1850 grains of sulphuric acid ; 1420 grains of nitric acid, &c., which numbers of course represent the specific gravities of those liquids.

A bottle, however, holding 1000 grains is often inconveniently large, and a small and thin globular phial, with a piece of thermometer tube ground into it by way of stopper, will be found more useful: such a phial should not weigh more than from 50 to 60 grains, and may contain between 4 and 500 grains of water. To use it, it should be accurately counterbalanced in a delicate pair of scales, and then filled with distilled water, and the stopper thrust in, the capillary opening in which allows a little to ooze out, and prevents the likelihood of bursting the phial; it is then to be wiped clean and dry, and again carefully weighed, by which the quantity of water it contains is ascertained; the water being poured out, it is next filled with the liquid whose specific gravity is required, taking care that it is of the same temperature as the water; we then weigh as before, and divide the weight by the former weight of water, the product gives the specific gravity required. Thus, suppose the phial to contain 425 grains of water at the temperature of 45°, it will be found to hold 5737.5 grains of pure mercury of the same temperature; and $5737.5 \div 425 = 13.5$ the specific gravity of mercury. Or, supposing the liquid lighter than water, such as alcohol, of which we may assume the phial to contain 350.5; then $350.5 \div 425 = 0.824$ the specific gravity of the alcohol under trial.

508. Among the metals, some are *malleable*, others *brittle*.

Malleability.

Malleability, or the capacity of being extended by the hammer belongs to the following metals, in the order following:

List and order of malleable metals.

Gold
Silver
Copper
Tin
Cadmium
Platinum
Lead
Zinc
Iron
Nickel
Palladium

Potassium, sodium, and frozen mercury, are also malleable.

509. The malleable metals are also *ductile*; that is, they admit of being drawn out into wires. They are arranged according to ductility as follows;

Of ductile metals.

Gold
Silver
Platinum
Iron
Copper
Zinc
Tin
Lead
Nickel
Paladium.

510. Different metallic wires are possessed of different degrees of *tenacity*, by which is meant the power of supporting a weight without breaking. According to the experiments of Guyton Morveau, the following are the weights capable of being sustained by wires $\frac{737}{1000}$ths of a line in diameter.—*Annales de Chimie*, lxxi.:

Metals possessing tenacity, with the power of each.

	lbs. decimal avoird. parts.
A wire of Iron suppports . . .	549.250
Copper	302.278
Platinum	274.320
Silver	187.137
Gold	150.753
Zinc	109.540
Tin	34.630
Lead	27.621

Brittle metals.

511. The folowing metals are brittle:

Antimony
Arsenic
Bismuth
Cerium
Chrome
Cobalt
Columbium
Manganese
Molybdenum
Tellurium
Tungsten
Titanium
Uranium.

Order of their hardness.

512. None of the metals are very *hard*, and many so soft as to yield to the nail. In the following table some of the metals are arranged in the order of their hardness;

Tungsten
Palladium
Manganese
Iron
Nickel
Platinum
Copper
Silver
Bismuth
Gold
Zinc
Antimony
Cobalt
Tin
Arsenic
Lead.

Elasticity and sonorousness belong to the hardest metals only.

Such are the essential physical characters of the metals; they also resemble each other in many of their chemical properties, as the following general observations show:

Action of heat.

513. *Action of Heat.*—The metals are all susceptible of fusion by heat, but the temperatures at which they liquefy are extremely various. Mercury is fluid at all common temperatures, and requires to be cooled to —39° before it congeals. Potassium melts at 150°, and sodium at 200°: arsenic at 360°; tin at 450°; lead at 600°; zinc at 700°; and antimony at 800°. Silver, gold, and copper require a bright cherry-red heat; iron, nickel, and cobalt, a white heat; manganese and palladium, an intense white heat; molybdenum, uranium, tungsten, and chrome, are only very imperfectly agglutinated at the highest temperatures of our furnaces; and titanium, cerium, osmium, iridium, rhodium, platinum, and columbium, require the intense heat produced by an inflamed current of oxygen and hydrogen, or that of Voltaic electricity.

At higher temperatures than that required for their fusion many of the metals are volatile, and may be distilled in close vessels. Mercury, arsenic, potassium, tellurium, and zinc, are volatile at a dull red heat. Gold and silver are converted into vapour when exposed to the intense heat of the focus of a burning lens; and several of the other metals boil and evaporate under similar circumstances. It is probable that this would happen to all of them, if raised to sufficiently high temperatures.

Action of oxygen.

514. *Action of Oxygen.*—When the metals are exposed at ordinary temperatures to the action of oxygen, or of common air, which produces analogous, though less powerful effects, they are very differently effected. If the gas be perfectly dry, very few of them suffer any change unless heated in it; they then lose their metallic characters, and form a very important series of compounds, the *metallic oxides*.

A few of the metals resist the action of heat and air so completely, that they may be kept in fusion in an open crucible for many hours without undergoing change. This is the case with gold and silver, and a few others; hence they were called *perfect* or *noble* metals: they may, however, be oxidized by the Voltaic flame; or by passing a strong electric discharge through them, when drawn into very fine wire.

Other metals readily absorb oxygen when exposed to a temperature approaching a red heat; as iron, mercury, nickel, *&c.*; others absorb it when in fusion, as lead, tin, antimony, *&c.*; others at lower, or even at common temperatures, as arsenic, manganese, sodium, potassium, *&c.*

That the metals have very different attractive powers in regard to oxygen is also shown by the circumstance of one metal being frequently oxidized at the expense of another; thus the oxide of mercury, heated with metallic iron, produces metallic mercury and oxide of iron; potassium, heated with oxide of manganese, becomes oxidized, and metallic manganese is obtained.

Some of the oxides are decomposed by mere exposure to heat, as those of gold, mercury, *&c.*; others require the joint action of heat, and some body having a high attraction for oxygen, such as charcoal. Thus when oxide of lead is heated with charcoal, carbonic acid gas is evolved, and metallic lead obtained.

Each metal has a certain definite quantity of oxygen with which it combines; and were the same metal unites in more than one proportion with oxygen, in the second, third, and other compounds, it is a multiple of that in the first, consistent with the law of definite proportions (46). Thus 100 parts of mercury combine with 4 of oxygen to produce the *protoxide*, and with 8 to produce the *peroxide*. Copper also forms two oxides; in the one 12.5 of oxygen are united to 100 of metal, and in the other 25.

Among the combinations of metals with oxygen, some are insoluble in water, or nearly so, and have neither taste nor smell; others are soluble and sour, constituting the *metallic acids*: others are soluble and alcaline, forming the *fixed alcalis* and *alcaline earths*. They are of all colours, and frequently the same metal united to different proportions of oxygen produces compounds differing in colour: thus we have the *black* and *red* oxide of mercury, the *white* and the *black* oxide of manganese, *&c.*

515. *Action of Chlorine.*—All the metals appear susceptible of combining with chlorine, and of producing a class of compounds which may be termed *metallic chlorides*. Action of chlorine.

There are a few of the metals which resist the action of chlorine at common temperatures, but when heated they all combine with it; some slowly, others rapidly and with intense ignition. Copper leaf, powdered antimony, arsenic, *&c.*, burn when thrown into the gas: mercury and iron inflame when gently heated in it; silver, gold, and platinum quietly absorb it.

The attraction of chlorine for metals is greater than that of oxygen; consequently, when a metallic oxide is heated in chlorine, oxygen is evolved, and a chloride formed. The insoluble chlorides are also formed by adding solution of chlorine, or of the soluble chlorides, or of muriatic acid, to the soluble metallic salts. Thus chloride of silver, which is insoluble, is thrown down from the soluble nitrate of silver by solution of chlorine, of muriatic acid, and of common salt.

The physical and chemical properties of the chlorides are extremely various. They are nearly of all colours. Some are unchanged by heat; others undergo decomposition. Some are soluble, others insoluble, in water. Several of them decompose water, giving rise to the formation of muriatic acid, and an oxide; or in some cases to a muriate. The same metal often forms more than one compound with chlorine, and these compounds are designated as the oxides. Thus we have the *protochloride* and *perchloride* of mercury, *&c.*

Many of the metals decompose muriatic acid in which case hydrogen is evolved, and a metallic chloride produced; and when metallic oxides are heated in muriatic acid, they generally give rise to the formation of a chloride and water.

Action of chloric acid.

516. *Action of Chloric Acid.*—The compounds of the metallic oxides with chloric acid are decomposed by heat with the copious evolution of oxygen, and a chloride generally remains: some of these salts have been long known, others only recently investigated. The *oxychlorates* have been scarcely examined.

Action of Iodine.

517. *Action of Iodine.*—Iodine aided by heat acts upon many of the metals, and produces *metallic iodides.* Some of these are soluble in water without decomposition; others decompose water and produce *hydriodates;* others are insoluble. The insoluble iodides may generally be formed by adding a solution of iodine or of hydriodic acid to the soluble metallic salts.

Iodine often combines in more than one proportion with metals, forming a *protiodide* and a *periodide.*

Action of Iodic acid.

518. *Action of Iodic Acid.*—The compounds of this acid with the metallic oxides have been but little examined: they are decomposed by heat, sometimes with the evolution of oxygen only; at others, iodine is also given off.

Action of hydrogen.

519. *Action of Hydrogen.*—Hydrogen forms permanent compounds with two of the metals only, namely, arsenic and tellurium. It appears to combine with each in two proportions, forming two solid compounds, the *hydrurets* or *hydrogurets* of arsenic and tellurium; and two gaseous compounds, *arsenuretted* and *telluretted hydrogen.* At high temperatures it dissolves potassium, forming *potassiuretted hydrogen gas.*

There are many of the metallic oxides, and a few of the chlorides, which are decomposed by hydrogen: the oxides are reduced with the formation of water, and the chlorides with the production of muriatic acid.

Action of water.

520. *Action of Water.*—Those metals which are speedily acted upon by common air and oxygen, are also generally susceptible of decomposing water; some of them rapidly, others slowly. There are some metals which are not acted upon by air deprived of moisture, nor by water deprived of air; but moist air, or water containing air, effect their oxidizement: this appears to be the case with iron.—Dr. Marshall Hall. *Quarterly Journal*, vii. 55.

Water combines with some of the metallic oxides, and produces *hydrated oxides*, or *metallic hydrates.* In these the relative proportion of water is definite. Some are easily decomposed by heat, as hydrate of copper; others retain water even when heated to redness, as hydrate of potassa.

521. *Action of Nitric Acid.*—As no metal is soluble in an acid except in the state of oxide, and as the greater number of metals are capable of decomposing nitric acid, and of resolving it into some of the other nitric compounds, nitric acid is a very generally acting solvent of these bodies. It dissolves all the metallic oxides and produces a numerous class of *nitrates*, which if prepared with heat and with excess of acid, generally contain the metal at its maximum of oxidizement. The nitrates are all decomposed by a red heat; they give off oxygen and nitrogen, either separate, or combined, and the metallic oxide remains. They are also decomposed when heated with sulphur, phosphorus, or charcoal; and sulphurous, phosphoric, and carbonic acids are formed; the phosphoric, being a fixed acid, remains united to the metallic oxide; while the sulphurous and carbonic acids are usually expelled. The nitrates are decomposed by sulphuric acid, nitric acid is evolved, and *sulphates* are formed. Action of nitric acid.

In the neutral nitrates the proportion of oxygen in the acid is to that in the base as 5 to 1. Thus in the nitrate of potassa 48 parts of potassa, containing 8 of oxygen, are combined with 54 of nitric acid, containing 40 of oxygen; and in the pernitrate of copper, 80 parts of peroxide of copper containing 16 of oxygen, are combined with 108 of nitric acid, containing 84 of oxygen.

522. *Action of Ammonia.*—At high temperatures some of the metals are capable of decomposing ammonia. Liquid ammonia dissolves several of the metallic oxides, and with some of them forms crystallizable compounds. The compounds of ammonia with the oxides of gold, silver, and platinum, detonate when heated, and the oxide and the ammonia are both decomposed.

523. *Action of Sulphur.*—All the metals appear capable of forming *sulphurets*. These are in some cases formed by heating the metal with sulphur; in others, by decomposing the sulphates; and in others, by the action of sulphuretted hydrogen. The sulphurets are in general brittle; some have a metallic lustre; others are without lustre. Some are soluble, others insoluble in water. Where the same metal forms two sulphurets, the sulphur in those containing the largest proportion is an exact simple multiple of the sulphur in those containing the smallest proportion. When the metallic sulphurets are heated some undergo no change, as those of sodium and potassium; others sublime unaltered as sulphuret of mercury; others lose a portion of their sulphur, and, if air be admitted, sulphurous acid escapes and the metal passes into the state of oxide, as sulphuret of lead; others again are entirely decomposed, the metal being completely reduced; this happens on heating sulphuret of platinum or of gold. It is doubtful whether any definite compounds of sulphur with the metallic oxides exist. Action of sulphur.

524. *Hyposulphurous acid* combines with the metallic oxides and produces a class of salts termed *hyposulphites*. Several of these have been examined by Mr. Herschel (*Edinburgh Philosophical Journal*, i.) In some of their characters they resemble the sulphites: they are easily soluble; of a bitter or sweet taste; and decomposed by a heat below redness, and by almost all other acids. Their solutions readily dissolve chloride of silver.

525. *Sulphurous acid* combines with many of the metallic oxides, producing *sulphites*; in some instances oxygen is transferred from the oxide to the acid, and sulphates result. Sulphites.

The *sulphites* are soluble in water, and have a sulphurous taste and smell. Exposed to moist air, they absorb oxygen, and pass into the state of sulphates. They are decomposed by sulphuric acid, which expels sulphurous acid, and the salts are converted into sulphates. When perfectly pure they are not affected by solution of baryta.

526. *Hyposulphuric acid* forms with the metallic oxides a class of hyposulphates which have been very imperfectly examined. They do not afford precipitates with solution of baryta.

Sulphates.

527. *Sulphuric acid*, in its concentrated state, is acted upon by a few of the metals only; when diluted, some of them are oxidized at the expense of the water, hydrogen is evolved, and the metallic oxide combines with the acid, producing a *sulphate*. In these cases the hydrogen evolved is the indicator of the quantity of oxygen transferred to the metal; every volume of hydrogen is the equivalent of half a volume of oxygen, and accordingly the production of 100 cubic inches of hydrogen, indicates the transfer of 50 of oxygen, or by weight of about 17 grains. As different metals unite to different weights of oxygen, they will obviously evolve different quantities of hydrogen. Thus, if one metal, to become soluble in sulphuric acid, require to be united with 15, and another with 30 per cent. of oxygen, the latter will evolve twice the volume of hydrogen, compared with the former.

As the evolution of hydrogen, during the solution of a metal in dilute sulphuric acid, is referable to its oxidizement, no hydrogen will be evolved by the action of the acid upon an oxide, but it will be merely dissolved.

The sulphates are an important class of salts. The greater number of them are soluble in water, and the solutions are rendered turbid by solutions of baryta. They are all decomposed at a red heat by charcoal, and most of them are thus converted into sulphurets; carbonic acid, and carbonic oxide, being at the same time evolved.

In the neutral sulphates the proportion of oxygen in the acid is to that in the base as 3 to 1. Thus sulphate of soda is composed of 32 soda containing 8 of oxygen, combined with 40 of sulphuric acid containing 24 of oxygen.

Sulphuretted hydrogen.

528. *Action of Sulphuretted Hydrogen.*—It seems doubtful whether any of the metals combine with sulphuretted hydrogen. It unites with several of their oxides, and forms *hydrosulphuretted oxides*. Many of these compounds are insoluble, and may be formed by adding a solution of sulphuretted hydrogen, or of hydrosulphuret of ammonia, to solutions of the respective metallic salts. Sometimes, however, a decomposition is effected in these cases, both of the sulphuretted hydrogen and of the oxide, and a metallic sulphuret is formed, the hydrogen combining with the oxygen of the oxide to form water, and the sulphur uniting to the metal. In a few cases the metallic oxide is reduced. The following table shows the effect of sulphuretted hydrogen and of hydrosulphuret of ammonia upon solutions of several of the metals, as far as colour of the precipitate is concerned.

METAL.	SOLUTION.	SULPHURETTED HYDROGEN.	HYDROSULPHURET OF AMMONIA.
MANGANESE	Neutral protomuriate	No precipitate	Copious ochre yellow
IRON	Neutral protosulphate	Blackish and small in quantity	Black and abundant
Ditto	Permuriate	Abundant black	Black
ZINC	Muriate	A little opalescent and then milky	Straw colour and copious
TIN	Acid protomuriate	Brown	Deep orange
Ditto	Acid permuriate	At first 0, then yellow and copious	Apple green
CADMIUM . . .	Muriate	Yellow	Yellow
COPPER	Protomuriate	Deep brown	Brown
Ditto	Pernitrate	Black	Brown and black
LEAD	Muriate and nitrate	Black	Brown and black
ANTIMONY . .	Tartrate of antimony and potassa	Deep orange-red	Bright orange
BISMUTH . . .	Tartrate of bismuth and potassa	Deep brown	Deep brown
COBALT	Muriate	0 but blackish	Copious black
URANIUM . . .	Sulphate	Brown	Blackish brown
TITANIUM . .	Acid muriate	0	Black
Ditto	Neutral sulphate	0	Green
CERIUM			
TELLURIUM .			
ARSENIC . . .	White oxide		
Ditto	Arsenic acid		
NICKEL	Sulphate	Brown	Black
MERCURY . .	Acid nitrate	Black, then gray, and black by excess of test	Black by excess of test
Ditto	Acid pernitrate	Ditto	Ditto
Ditto	Corrosive sublimate	Brown by excess of test	Ditto
RHODIUM . . .			
PALLADIUM .			
SILVER	Nitrate	Black, and films of reduced silver	Brown
GOLD	Muriate	Black, and reduced gold	Yellow
PLATINUM . .	Nitrate	Deep brown	Pale brown

Colour of precipitates by sulphorated hydrogen.

529. *Action of Phosphorus.*—Phosphorus combines with the greater number of the metals, forming a series of *metallic phosphurets.* There are two methods of forming them; either by heating a mixture of phosphorus and the metal, or projecting phosphorus upon the metal previously heated to redness; or by heating a mixture of the metal or its oxide, with phosphoric acid and charcoal. These phosphurets have a metallic lustre; if they contain a difficultly fusible metal, they are more fusible than the metal they contain; if an easy fusible metal,

Action of phosphorus.

less so. They are mostly crystallizable, and totally or partially decomposable at a high temperature. The greater number of the phosphurets have only been examined by Pelletier,—*Annales de Chimie*, Tom i. *et* xiii. and *Mémoires et Observations de Chimie*.

Phosphates. 530. The *metallic phosphates* may be formed either by dissolving the oxides in phosphoric acid, or by adding a solution of phosphoric acid, or of an alcaline phosphate, to solutions of those metals which form insoluble or difficultly soluble phosphates. The greater number of the phosphates are decomposed by ignition with charcoal ; and those containing volatile oxides are volatilized at high temperatures.

In the neutral phospates the quantity of oxygen in the acid is to that in the base as 2 to 1. Thus phosphate of soda consists of 32 soda containing 8 oxygen, and 28 phosphoric acid containing 16 of oxygen.

531. When phosphorus is introduced into the solutions of those metals which have but a feeble attraction for oxygen, it reduces them to the metallic state. Thus gold, silver, and platinum are thrown down by immersing a stick of phosphorus into their respective solutions.

Action of carbon. 532. *Action of Carbon.*—Carbon unites to very few of the metals, and of the metallic carburets, one only is of importance, namely carburet of iron, or *steel*.

Carbonates. 533. *Carbonic acid* unites with the greater number of the metallic oxides and forms *Carbonates*, of which the distinctive characters have already been noticed ; many of them are of difficult solubility, and may be formed by adding an alcaline carbonate to the metallic solution. Of the carbonates some are entirely, and others only partially decomposed at a red heat. Carbonate of magnesia, for instance, loses the whole of its carbonic acid at a red heat ; carbonate of potassa retains it ; and bi-carbonate of potassa loses one-half and passes into the state of carbonate.

Action of Boron. 534. *The action of Boron* upon the metals has not been investigated, though it appears from the experiments of Descotils, (*Recherches Physico-chymiques de* M. M. Gay-Lussac et Thenard) to be capable of uniting to platinum and iron. These compounds may be called *borurets*. The metallic *borates* are numerous but mostly unimportant.. Many of them are insoluble and easily formed by adding solution of boracic acid, or a soluble borate to the metallic solution.

Action of metals upon each other. 535. *Action of the Metals upon each other.*—The metals may for the most part be combined with each other, forming a very important class of compounds, the *metallic alloys*. Various processes are adopted in the formation of alloys depending upon the nature of the metals. Many are prepared by simply fusing the two metals in a covered crucible ; but if there be a considerable difference in the specific gravity of the metals, the heavier will often subside, and the lower part of the bar or ingot, will differ in composition from the upper ; this may be prevented by agitating the alloy till it solidifies. Mr. Hatchett found that when an alloy of gold and copper was cast into bars, the moulds being placed perpendicularly, the upper part of the bar contained more copper than the lower.—*Phil. Trans*. 1803.

Where one of the metals is very volatile, it should generally be added to the other after its fusion ; and if both metals be volatile, they may be sometimes united by distilling them together.

It has been a question whether alloys are to be considered as compounds, or as mere mixtures; but their properties leave little doubt of their being real compounds, and in some cases they are found to unite in definite proportions only; and it is probable that all the alloys contain a definite compound of the two metals.

536. The principal characters of the alloys are the following:

Characters of alloys.

i. We observe a change in the ductility, malleability, hardness, and colour. Malleability and ductility, are usually impaired, and often in a remarkable degree: thus gold and lead, and gold and tin, form a brittle alloy. The alloy of copper and gold is harder than either of its component parts; and a minute quantity of arsenic added to copper, renders it white.

ii. The specific gravity of an alloy is rarely the mean of its component parts, in some cases an increase, in others a diminution of density having taken place, as shown by the following Table from Thenard.—*Traité de Chimie*, Vol. i. p. 394.

Specific gravity of alloys compared with their constituents.

Alloys possessed of greater specific gravity than the mean of their components.	Alloys having a specific gravity inferior to the mean of their components.
Gold and Zinc	Gold and Silver
Tin	Iron
Bismuth	Lead
Antimony	Copper
Cobalt	Iridium
Silver and Zinc	Nickel
Lead	Silver and Copper
Tin	Copper and Lead
Bismuth	Iron and Bismuth
Antimony	Antimony
Copper and Zinc	Lead
Tin	Tin and Lead
Palladium	Palladium
Bismuth	Antimony
Antimony	Nickel and Arsenic
Lead and Bismuth	Zinc and Antimony
Antimony	
Platinum & Molybdenum	
Palladium and Bismuth	

iii. The fusibility of an alloy is generally greater than that of its components. Thus platinum, which is infusible in our common furnaces, forms, when combined with arsenic, a very fusible alloy; and an alloy of certain proportions of lead, tin, and bismuth is fusible at 212°, a temperature several degrees below the melting point of its most fusible constituent.

iv. Alloys are generally more oxidizable than their constituents taken singly; a property which is, perhaps, partly referable to the formation of an electrical combination. Where an alloy consists of two metals, the one easily and the other difficultly oxidizable, it may be decomposed by exposing it to the action of heat and air, the former metal being converted into an oxide; its last portions, however, are often not easily separated, being protected by combination with the least oxidable metal. An alloy of three parts of lead and one of tin is infinitely more oxidizable than either of its components, and easily burns at a dull red heat.

Action of acids on alloys.

v. The action of acids on alloys may generally be anticipated by a knowledge of their effects upon the constituent metals; but if a soluble metal be alloyed with an insoluble one, the former is often protected by the latter from the action of an acid. Thus, silver alloyed with a large quantity of gold, resists the action of nitric acid in consequence of the insolubility of the latter metal in that acid; and, in order to render it soluble, it is requisite that it should be made to form about a fourth part of the alloy, in which case the nitric acid extracts it, and leaves the gold in an insoluble film or powder.

537. Various classifications of the metals have been adopted by chemical authors; some dependent upon their physical, others upon their chemical properties. The former can scarcely be considered as adapted to chemical inquiry, and the latter involve numerous difficulties in consequence of the gradual transition of metals of one class into those of another. I shall consider the metals in the order in which they are set down in the following Table, and which is nearly that of their respective attractions for oxygen.

Metals in the order of their attractions for oxygen.

1 Potassium
2 Sodium
3 Lithium
4 Calcium
5 Barium
6 Strontium
7 Magnesium

8 Manganese
9 Iron
10 Zinc
11 Tin
12 Cadmium

13 Copper
14 Lead
15 Antimony
16 Bismuth
17 Cobalt
18 Uranium
19 Titanium
20 Cerium
21 Tellurium
22 Selenium

23 Arsenic
24 Molybdenum
25 Chromium
26 Tungsten
27 Columbium

28 Nickel
29 Mercury
30 Osmium
31 Iridium
32 Rhodium
33 Palladium
34 Silver
35 Gold
36 Platinum

37 Silicium
38 Alumium
39 Zirconium
40 Glucium
41 Yttrium
42 Thorinum

Of these metals the first seven produce alcaline oxides which are very difficult of reduction; and they rapidly decompose water at all temperatures, a character which announces their powerful attraction for oxygen; the next five decompose water when their temperature is raised to redness: the ten following do not decompose water at a red heat; nor do the next five, which produce acids by uniting to oxygen. The oxides of these twenty-seven metals are not reducible by heat alone, though some of them, when heated, give out a portion of oxygen. The nine metals which next follow, osmium excepted, have a comparatively feeble attraction for oxygen; and when their oxides are heated, they are reduced to the metallic state. The last six metals are placed in the list from analogy; they are only known in the state of oxides, which have not hitherto been reduced.

SECTION I. *Potassium.*

538. THIS metal was discovered in 1807 by Sir Humphry Davy,—(*Philos. Trans.* 1808). He obtained it by submitting caustic potassa, or potash, to the action of Voltaic electricity : the metal was slowly evolved at the negative pole. By this process, however, it could only be procured in very minute quantities ; and various other methods have been devised, of which the best is that described by Gay-Lussac and Thenard. (*Recherches Physico-chymiques.*) It is as follows :

Process for obtaining it.

539. A sound and perfectly clean gun-barrel is bent, as shown in the annexed sketch. It is then covered with an infusible lute between the letters O and E (fig. 1.) and the interior of the luted part is filled with c[illegible] iron turnings. Pieces of fused potassa are then loosely placed in the barrel between E and C. A A is a copper tube and small receiver, which are adapted to the extremity O, and to each other by grinding. This apparatus is next transferred to the furnace, arranged as shown in fig. 2, X and T representing two glass tubes dipping into mercury. The furnace is supplied with air by a good double bellows entering at B, and a small wire basket G, is suspended below the space E C. The part of the barrel in the furnace is now cautiously raised to a white heat, and the escape of air by the tube X shews that all is tight. Some burning charcoal is then put at the end E, of the cage G, which causes a portion of potassa to liquefy and fall into the low part of the barrel upon the iron. Hydrogen gas instantly escapes by the tube X, and attention must now be had to keep the copper tubes A A cool, by laying wet cloths upon them. When the evolution of gas ceases, fresh charcoal is placed under the potassa, and so on till the whole has passed down ; if too much potassa be suffered to fall at once, the extrication of gas at X will be very violent, which should be avoided. If the space between A and O should become stopped by potassium, gas will issue by the tube T (which must always be under a greater pressure of quick-

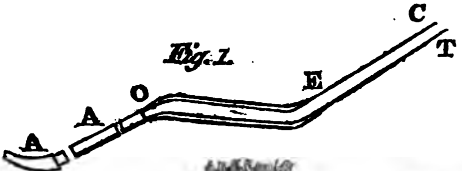
Fig. 1.

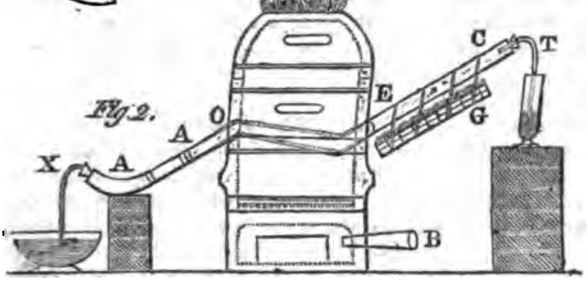
Fig. 2.

silver than the tube x), and it may be fused by applying hot charcoal to the tube, when the gas will again appear at x and cease at T. When the operation is concluded, the tubes x and T are removed, and corks quickly applied to the holes; and when the apparatus is cool, the barrel is carefully removed from the furnace, and a little naphtha suffered to run through it. The potassium is found in globules in the tube and receiver A A, and considerable portions often lodge at O. The success of this operation is certain, if the heat has been sufficient; but the barrel, if not very carefully covered with lute, is apt to melt, and much, if not the whole of the product is lost.

Character. 540. Potassium is a white metal of great lustre. It instantly tarnishes by exposure to air. It is ductile, and of the consistency of soft wax. Its specific gravity is 0.85. At 150° it enters into perfect fusion; and at a bright red heat rises in vapour. At 32° it is a hard and brittle solid. If heated in air it burns with a brilliant white flame. It is an excellent conductor of electricity and of heat.

Combination with oxygen. 541. *Potassium and Oxygen.*—When potassium is thrown into water it instantly takes fire; hydrogen gas is evolved, and *oxide of potassium* or *potassa*, is found dissolved in the water. The quantity of hydrogen evolved in this experiment becomes the indicator of the proportion of oxygen which has been transferred to the metal; 100 parts of potassium are thus found to absorb 20 of oxygen; and if this be considered a protoxide, then 20 : 100 : : 8 : 40,—so that 40 will be the number representing potassium, and 40 P. + 8 O. = 48 will represent dry oxide of potassium.

542. Potassa, in the state it is usually met with in laboratories, contains a considerable portion of water, from which it may be freed by the action of iron at high temperatures, and there always remains in the barrel, after the above experiment, a large portion of *dry potassa.* It is a hard grey substance, which, by water, is slowly converted into the *hydrated oxide*, or caustic potash, which may be obtained by evaporation. This substance, after exposure to a red heat, is white and very soluble in water; it may be considered as a compound of 1 proportional of protoxide of potassium = 48 + 1 proportional of water 9 and its number = 57.

Peroxide. 543. *Peroxide of Potassium.*—If the metal be heated in considerable excess of oxygen, it burns with intense heat and light, and an orange-coloured substance is obtained, which consists of 40 potassium + 24 oxygen = 64. This peroxide of potassium, when put into water, effervesces, oxygen is given off, and a solution of the hydrated protoxide is obtained. Peroxide of potassium is also formed by passing oxygen over potassa heated to redness.

Mode of procuring caustic potassa. 544. The *hydrated protoxide* or *caustic potash*, is procured in our laboratories by decomposing its carbonate by lime. The best process consists in boiling in a clean iron vessel, carbonate of potassa, (obtained by calcining tartar) with half its weight of pure quick lime, in water. The ley is strained through clean linen, concentrated by evaporation, again strained, and set by in a well-stopped bottle till it admits of being decanted clear from the sediment. The clear solution is to be evaporated to dryness. It is often cast into sticks for the use of surgeons, who employ it as a caustic, and in this state it generally contains some peroxide, and therefore evolves oxygen when dissolved in water. It is the *potassa fusa* of the *London Pharmacopœia.* It may be further purified by the action of alcohol, which dissolves the pure hydrate and leaves earthy and other impurities; the alcohol is then driven off by heat. In this case the alcohol is always in some measure acted upon by the potassa, and a portion of carbonaceous matter deposited, so that it should be allowed to remain as short a time as possible combined with the alcali. Having obtained the dry caustic alcali by lime, it may be boiled in a silver basin with highly rectified alcohol for a few minutes, and then set by in a stopped phial; when the impurities are deposited, the alcoholic solution may be poured off and rapidly evaporated to dryness in a silver basin as before: the heat may then be raised so as to fuse the potassa, which, on cooling, should be broken up and preserved in well-closed phials.

Hydrate of Potassa thus purified is white, very acrid and corrosive, and at a bright red heat evaporates in the form of white acrid smoke. It quickly absorbs moisture and carbonic acid from the air, and at 60° one part of water dissolves two. It may be crystallized in octoedrons. It is highly alcaline, and being exclusively procured from vegetables was formerly called *vegetable alcali*. When touched with moist fingers it has a soapy feel, in consequence of its action upon the cuticle. In the fused state it produces heat when dissolved in water; but in its crystallized state it excites considerable cold, especially when mixed with snow. At a natural temperature of 30°, M. Lowitz found that equal weights of crystallized potassa and snow depressed the thermometer 45°.—*Annales de Chimie*, xxii. Characters.

545. *Chlorine and Potassium* act very energetically on each other, and produce the white compound which has been called *muriate of potash*, but which is a true *chloride of potassium*, consisting of 40 P. + 36 Ch. When potassium is heated in gaseous muriatic acid, this compound is formed, and hydrogen is evolved. It dissolves without decomposition in three parts of water at 60°. It crystallizes in cubes; its taste is saline and bitter. In old pharmacy it was called *salt of Sylvius*; also, *regenerated sea-salt*. Chloride.

546. *Chlorate of Potassa* is formed by passing chlorine through a solution of potassa. Chloride of potassium is one of the results, the other is a salt in brilliant rhomboidal tables (formerly called oxymuriate of potash), the chlorate.

This salt is prepared, upon the large scale, by charging one or two Wolfe's bottles with solution of carbonate of potassa, and passing chlorine slowly through it: the gas is absorbed, and the liquor effervesces chiefly from the escape of carbonic acid; when this has ceased, the liquor may be put aside in a cold dark place for about 24 hours, when it will be found to have deposited a considerable portion of the crystallized chlorate, which may be taken out, drained, and purified by solution in hot water, which, during cooling again, deposits the salt in white crystalline scales. The liquor is generally of a pinkish hue, from the presence of manganese.

The taste of this salt is cooling and austere. When triturated it appears phosphorescent. When exposed to a dull red heat it decrepitates, fuses, and gives out oxygen, and chloride of potassium remains. It is soluble in 18 parts of cold and 2.5 of boiling water. It acts very energetically upon many inflammables and triturated with sulphur, phosphorus, and charcoal, produces inflammation and explosion. A mixture of three parts of this chlorate with one of sulphur, detonates loudly when struck upon an anvil with a hammer, and even sometimes explodes spontaneously; hence it should not be kept ready mixed. Chlorate of potassa was proposed by Berthollet as a substitute for nitre in gunpowder. The attempt was made at Essone in 1788; but, as might have been expected, no sooner was the mixture of the chlorate with the sulphur and charcoal submitted to trituration, than it exploded with violence, and proved fatal to several people. With phosphorus the detonation is dangerously violent. These phænomena depend upon the decomposition of the chloric acid. The action of sulphuric acid upon chlorate of potassa has already been adverted to (217). If, instead of distilling the yellow mixture of the acid and chlorate with the caution there described, it be heated to about 150°, it suddenly explodes. The theory of the production of chloric oxide appears to be as follows: the sulphuric acid expels one proportional of oxygen from the chlorate, and the potassium absorbs one proportional to produce potassa, which gives rise to sulphate of potassa; the remaining four proportionals of oxygen and one of chlorine form the oxide of chlorine.

When sulphuric acid is poured upon mixtures of this salt and combustibles, instant ignition ensues in consequence of the evolution of oxide of chlorine, and when sulphuric or nitric acids are poured upon similar mixtures under water by means of a long funnel, inflammation also ensues.

A few grains of chlorate of potassa put into a tea-spoonful of muriatic acid, and then diluted with water, form an extemporaneous bleaching liquor.

Chlorate of Potassa consists of one proportional of chloric acid and one of potassa, or 76 C. A. + 48 P. Its ultimate components, therefore, are

6	proportionals of oxygen .... 5 in the acid and 1 in the alcali	= 48
1	proportional of chlorine	= 36
1	———— potassium. ..	= 40
		124

547. *Oxychlorate of Potassa* may be formed by moistening one part of chlorate of potassa with three of sulphuric acid, and subsequently carefully heating the mass till it becomes white: in this state it consists of bisulphate and oxychlorate of potassa, which may be separated by solution and crystallization, the former being much more soluble in cold water than the latter salt.

Oxychlorate of potassa does not change vegetable colours, nor is it altered by exposure to air. It requires rather more than 50 parts of water at 60° for its solution. It is insoluble in alcohol. It crystallizes in elongated octoëdrons. When mixed with its own weight of sulphuric acid, and distilled at 280°, solution of oxychloric acid passes over. It may be decomposed by exposure to a temperature of 412°. Oxygen is given off, and chloride of potassium remains in the retort. This salt is thus found to consist of one proportional of oxychloric acid = 92 + one proportional potassa = 48, and its representative number is therefore = 140.

548. *Iodide of Potassium.* Iodine and potassium act upon each other very energetically, and a crystalline compound is obtained, white and fusible. The hydriodic acid and potassa produce a similar compound.

549. When iodine is put into solution of potassa, the results are *iodate of potassa* and iodide of potassium: the latter may be removed by alcohol.

Iodate of Potassa, is a white difficultly soluble salt, which at a red heat gives out oxygen, and is converted into iodide of potassium.—Gay-Lussac, *Ann. de Chim.*, xci.

550. *Potassium and Hydrogen.*—When potassium is heated in hydrogen, it absorbs a portion of the gas, and produces a grey and highly inflammable *hydruret*. When hydrogen and potassium are passed together through a white hot tube, the gas dissolves the metal, and produces a spontaneously inflammable *potassiuretted hydrogen gas.* Both these compounds are usually formed during the operation for obtaining potassium by the gun-barrel.

551. *Nitrate of Potassa—Nitre—Saltpetre.* This salt is an abundant natural product, and is principally brought to this country from the East Indies, where it is produced by lixiviation from certain soils.

The rough nitre imported from the East Indies is in broken crystals of a brown colour, and more or less deliquescent: exclusive of other impurities, it often contains a very considerable proportion of common salt, which re-acting upon the nitre, induces the production of nitrate of soda and chloride of potassium.

In Germany and France it is artificially produced in what are termed nitre-beds. Thenard (*Traité de Chemie Elémentaire*, Tom. ii., p. 511.) has described the French process at length. It consists in lixiviating old plaster rubbish, which when rich in nitre, affords about five per cent. Refuse animal and vegetable matter which has putrified in contact with calcareous soils produces nitrate of lime, which affords nitre by mixture with subcarbonate of potassa. In the same way it is abundantly produced in some parts of Spain. Exudations containing saltpetre are not uncommon upon new walls, where it appears to arise from the decomposition of animal matter contained in the mortar. It was long ago shown by Glauber, that a vault plastered over with a mixture of lime, wood-ashes, and cows' dung, soon becomes covered with efflorescent nitre, and that after some months, the materials yield, on lixiviation, a considerable proportion of that salt.

Nitre crystallizes in six-sided prisms, usually terminated by dihedral summits; it dissolves in 7 parts of water at 60°, and in its own weight at 212°. Its taste is cooling and peculiar. It consists of one proportional of acid = 54 + one proportional of potassa = 48. Or of

6 proportionals of oxygen . . . . . 5 in the acid and 1 in the alcali . .	48
1 proportional of nitrogen	14
1 ———— potassium	40
	102

552. When exposed to a white heat, nitre is decomposed into oxygen, nitrogen, and dry potassa. It fuses at a heat below redness, and congeals on cooling into cakes called *sal prunelle.*

If the temperature of nitre be so far increased as to allow a portion of oxygen to escape, the remaining salt, as Scheele first observed, remains neutral, and in this state it has been considered as forming a *nitrite of potassa.*

Nitre is rapidly decomposed by charcoal at a red heat; and, if excess of charcoal be used, the results are carbonic oxide and acid, nitrogen, and subcarbonate of potassa, formerly called *nitrum fixum*, and *white flux*.

The old chemists used to perform this detonation in retorts connected with capacious receivers, which were generally blown to pieces; sometimes they succeeded in obtaining a little acidulated water, which they called *clyssus of nitre*, and attributed to it wonderful medical virtues.

When phosphorus is thrown upon nitre, and inflamed, a vivid combustion ensues, and a phosphate of potassa is formed. Sulphur sprinkled upon hot nitre burns and produces a mixture of sulphate and sulphite of potassa. This salt used formerly to be employed in medicine, under the name of *Glaser's polychrest salt*. Most of the metals, when in filings or powder, detonate and burn when thrown on red-hot nitre; some of the more inflammable metals produce in this way a considerable explosion.

553. A mixture of three parts of nitre, two of dry subcarbonate of potassa, and one of sulphur, forms *fulminating powder*. If a little of this compound be heated upon a metallic plate, it blackens, fuses, and explodes with much violence, in consequence of the rapid action of the sulphur upon the nitre.

554. *Gunpowder* consists of a very intimate mixture of nitre, sulphur, and charcoal. The proportions vary. The following are those usually employed:

	Common Gunpowder.	Shooting powder.	Shooting powder.	Miners' powder.
Saltpetre . .	75.0	78	76	65
Charcoal . .	12.5	12	15	15
Sulphur . . .	12.5	10	9	20

The latter contains the smallest quantity of saltpetre, as it requires less *quickness* or *strength*. The ingredients are *perfectly* mixed, moistened, beaten into a cake which is afterwards broken up, granulated, dried, and for the finest powder polished by attrition. The violence of the explosion of gunpowder depends upon the sudden production of gaseous matter, resulting from the action of the combustibles upon the nitre. Carbonic oxide, carbonic acid, nitrogen, and sulphurous acid, are the principal gaseous results; and the solid residue consists of subcarbonate, sulphate, and sulphuret of potassa, and charcoal.—CRUICKSHANKS, *Nicholson's Journal*, iv.

Gunpowder may, it is said, be inflamed by a violent blow; if mixed with powdered glass, or any other harder substance, and struck with a heavy hammer upon an anvil, it almost always explodes.

555. *Potassium unites to Sulphur* with the evolution of much heat and light, and forms a grey compound, which, when acted upon by water, produces sulphuretted hydrogen. It consists of 40 P. + 16 S. = 56.

556. *Potassa and Sulphur*, when fused together, form a red *sulphuret of potassa*. (*Liver of Sulphur.*) Its taste is bitter and acrid. It is deliquescent and very soluble in water, forming a yellow solution of *hydrosulphuret of potassa*. The action of the sulphuret of potassa on water is complicated, and has been variously explained. By some this is

considered as a compound of *potassium* and sulphur; in which case, when acted upon by water, hydrogen is imparted to the sulphur, and oxygen to the potassium; and a sulphuret of potassa with excess of sulphur (or sulphuretted sulphuret of potassa) is formed. If we consider the sulphuret as consisting of *potassa* and sulphur, then, the oxygen as well as the hydrogen of the water, must be transferred to the sulphur, and sulphuric and sulphurous acid, and sulphuretted hydrogen, would be formed; and generally when the solutions of the *livers of sulphur* are examined, sulphate and sulphite of the alcali, are found. On the whole however, it appears most probable, that when sulphur and the alcalies are fused together at a high temperature, the latter undergo decomposition, and that sulphurets of their metallic bases are actually formed. VAUQUELIN, *Ann. de Chim.*

557. *Hyposulphite of Potassa* is formed by decomposing hydrosulphuret of potassa by sulphurous acid and evaporating to a pellicle, when it forms acicular crystals, of a cooling bitter taste, and deliquescent.

558. *Sulphite of Potassa* is formed by passing sulphurous acid into a solution of potassa, and evaporating out of the contact of air. Rhomboidal plates are obtained, white, of a sulphurous taste, and very soluble. By exposure to air, they pass into sulphate of potassa.

559. *Sulphate of Potassa* is the result of several chemical operations carried on upon a large scale in the processes of the arts. It may be formed directly by saturating sulphuric acid by potassa. It is the *sal de duobus* of the old chemists: the *potassæ sulphas* of the *London Pharmacopœia.* Its taste is bitter. It crystallizes in short six-sided prisms, terminated by six-sided pyramids. The body of the prism is often wanting and the triangular-faced dodecaëdron results. This salt dissolves in 16 parts of cold, and 5 of boiling water, and in consequence of its difficult solubility, it is thrown down in a white granular powder, when sulphuric acid is added to a moderately strong solution of potassa. Exposed to a red heat it melts, but is not decomposed. Heated with charcoal it produces sulphuret of potassa. It consits of

1 proportional of acid = 40
1 ———————— alcali = 48
88

560. *Bi-sulphate* or *Supersulphate of Potassa* is formed by adding sulphuric acid to a hot solution of sulphate of potassa, or by boiling sulphate of potassa with sulphuric acid. The first crystals which form are in delicate needles of an acid taste, soluble in 2 parts of water at 60°, and consist of

2 proportionals of acid . . = 80
1 ———————— potassa = 48
128

Bi-sulphate of Potassa is also formed in the distillation of equal parts of nitre and sulphuric acid: nitric acid passes over, and a residuary bi-sulphate of potassa is produced, commonly known under the name of *sal enixum.* It is the *arcanum duplicatum,* or *panacea Holsatica* of old pharmaceutists. It is used for cleansing coin and other works in metal; and has a place in the *London Pharmacopœia.*

The following diagram will illustrate the formation of this salt, and of liquid nitric acid, in the distillation of two proportionals of sulphuric acid with one of nitre:

	Potash.	Sulphate of potash.	Muriate of potash.	Insoluble residue.	Carbonic Acid and water.	TOTAL.
Potash of Russia	772	65	5	56	254	1152
" America	857	154	20	2	119	1152
American Pearl-ash . . .	754	80	4	6	308	1152
Potash of Treves	720	165	44	24	199	1152
" Dantzic	603	152	14	79	304	1152
" Vosges	444	148	510	34	304	1440

A saturated solution of carbonate of potassa in water contains about 48 per cent. of the salt, and has a specific gravity of 1.5.

570. *Bi-carbonate of Potassa* is formed by passing a current of carbonic acid into a solution of the subcarbonate. By evaporation crystals are obtained in the form of four-sided prisms, with dihedral summits. Their taste is only slightly alcaline, and they require for solution four parts of water, at 60°. Exposed to a red heat, carbonic acid is evolved, and carbonate of potassa remains. This bi-carbonate consists of

2 proportionals of carbonic acid = 44
1 ———————— potassa, = 48
—
92

In its crystalline form it contains water equal to one proportional; and, therefore, consists of

92 carbonate
9 water
—
101

In the *London Pharmacopœia* the more expensive method of obtaining this salt by the action of carbonate of ammonia on carbonate of potassa is resorted to.

The following proportions may be used for the preparation of bi-carbonate of potassa upon the large scale: 100 lbs. of purified carbonate of potassa are dissolved in 17 gallons of water, which, when saturated with carbonic acid, yields from 28 to 30 lbs. of crystallized bi-carbonate; 50 lbs. of carbonate of potassa are then added to the mother liquor, with a sufficient quantity of water to make up 17 gallons, and the operation repeated.

The subcarbonate and carbonate of potassa, are both decomposed by lime, which deprives them of carbonic acid; hence the use of that earth in the process for obtaining pure *potassa*.

571. Potassium heated in cyanogen absorbs the gas, and produces a grey *cyanuret of potassium*, which by the action of water becomes

hydrocyanate of potassa. This salt speedily decomposes and becomes converted into carbonic acid and ammonia.

572. *Borate of Potassa* is a salt which has been scarcely examined; it may be prepared by boiling boracic acid in solution of potassa, or by exposing a mixture of boracic acid and nitre to a bright red heat; it furnishes by solution and evaporation quadrangular prisms, permanent in the air.

573. The salts of potassium are soluble in water, and afford no precipitates with pure or carbonated alcalis. They produce a precipitate in muriate of platinum, which is a triple compound of potassa, oxide of platinum, and muriatic acid. They are not changed by sulphuretted hydrogen, nor by ferro-prussiate of potassa. Added to sulphate of alumina, they enable it to crystallize, so as to form alum.

◆

SECTION II. *Sodium.*

574. SODIUM, discovered by Sir H. Davy in 1808, is obtained from soda by an operation analogous to that for procuring potassium from potassa (539). *It is soft, malleable, and easily sectile. Its specific gravity is 0.97. In colour it resembles lead. It fuses at about 190°,* and is volatile at a white heat. It burns when heated in contact with air, and requires the same cautions to preserve it as potassium.

575. *Sodium and Oxygen.*—When sodium is thrown upon water, it produces violent action, but the metal does not in general inflame; hydrogen is evolved, and a solution of soda is procured. By the quantity of hydrogen evolved, we learn that *soda* (*protoxide of sodium*) consists of about 75 sodium and 25 oxygen *per cent.*; and, if it be considered as the protoxide, the number representing the metal will be 24, and soda will consist of 24 S. + 8 O., and be represented by 32.

576. By heating sodium in oxygen, it burns vividly, and an orange-coloured *peroxide* is formed, consisting of 24 S. + 12 O., and which, by the action of water, evolves oxygen, and produces a solution of the protoxide.

577. *Soda*, as it usually occurs in the laboratories, is obtained from the carbonate, by the action of lime and alcohol, as described under the head *potassa* (544). It consists of 32 protoxide of sodium + 9 water, and is represented by 41. When soda is exposed to air, it soon becomes covered with an efflorescence of carbonate of soda. Its colour is greyish white, and it requires a red heat for fusion.

578. Soda is distinguished from potassa, by forming an *efflorescent* paste when exposed to the atmosphere; potassa under the same circumstances *deliquesces*. If excess of tartaric acid be added to a solution of soda there is no precipitation; but in solution of potassa it occasions a deposit of a number of minute crystals. Solution of soda occasions no precipitate when added to solution of muriate of platinum. Solution of potassa occasions a yellow precipitate in solution of platinum. In combination with acids it produces a perfectly distinct class of salt.

579. *Chloride of Sodium.*—Sodium, when heated in chlorine, burns and produces a white compound, of a pure saline flavour, soluble in

2½ parts of water at 60°, and forming cubic crystals. It has all the properties of *common salt* or *muriate of soda*, and consists of

1 proportional of chlorine = 36
———————— sodium = 24
—
60

This compound is decomposed, when heated with potassium: sodium and chloride of potassium are the results.

When soda is heated in chlorine, oxygen is evolved; when heated in muriatic acid, water is formed, and in both cases chloride of sodium is the product.

580. Common salt exists abundantly in nature, both as a solid fossil and dissolved in water. Immense masses of it are found in Cheshire, where it is known under the name of *rock salt*.

581. When heated, chloride of sodium falls into pieces with a crackling noise, or *decrepitates*. At a red heat it fuses without undergoing any decomposition, and on cooling concretes into a hard white mass. It is scarcely more soluble in boiling than in cold water, and nearly insoluble in alcohol. When pure it does not alter by exposure to air; obtained by slow or spontaneous evaporation, it crystallizes in solid cubes; but when procured, as is usually the case at a boiling heat, by removing its crystals from the surface of its solution whilst evaporating, it exhibits the form of a hollow quadrangular pyramid. A concise account of the different methods of manufacturing salt will be found in AIKIN's Dictionary.—*Art. Muriate of Soda.*

582. Chloride of sodium is decomposed by moist carbonate of potassa, and chloride of potassium and carbonate of soda are the results. In the common process for obtaining muriatic acid it is decomposed by sulphuric acid. (250). In this decomposition there is a transfer of the oxygen contained in the water of the sulphuric acid to the sodium of the salt, the chlorine of which combines with the hydrogen of the water to produce muriatic acid gas. The oxide of sodium unites with the dry sulphuric acid to produce sulphate of soda. (590).

Common salt is of most extensive use as a preservative of food, and as a condiment. Glauber first obtained muriatic acid from it, and the existence of soda in it was first shown by Duhamel.

583. *Chlorate of Soda* was procured by Mr. Chenevix (*Phil. Trans.* 1802), by the same process as chlorate of potassa, but not possessing less solubility than chloride of sodium, the two substances are difficultly separable. Vauquelin obtained it by saturating chloric acid with soda. Its crystals resemble those of chlorate of potassa, its taste is also nearly similar.

584. *Sodium and Iodine* act upon each other with the same phænomena as potassium, and an *iodide of sodium* is obtained. The hydriodic acid and soda produce a similar compound. It is deliquescent, and its solution yields quadrangular crystals.

585. *Iodate of Soda* is made by dissolving iodine in solution of soda; a white compound forms, which is the iodate with a portion of hydriodate of soda; the latter may be removed by alcohol. Iodate of soda forms small prismatic tufted crystals, which, when heated, afford oxygen and iodide of sodium.—GAY-LUSSAC, *Annales de Chimie*, xci.

586. *Nitrate of Soda* crystallizes in rhombs, soluble in three parts of water at 60°, and in less than its weight at 212°. It has a cool sharp flavour, and is somewhat deliquescent. It consists of 32 soda + 54 nitric acid. It is often found in crude nitre, resulting apparently from the decomposition of common salt. It is the *cubic nitre* of old writers.

587. *Sulphuret of Sodium and of Soda.* See *Potassium.* (556). The sulphurets exhibit nearly similar properties.

588. *Hyposulphite of Soda* is formed as hyposulphite of potassa. (557.) It is difficultly crystallizable, deliquescent, of an intensely bitter taste, and insoluble in alcohol. Its aqueous solution readily dissolves moist chloride of silver.

589. *Sulphite of Soda* is crystallizable in transparent four and six-sided prisms, soluble in four parts of water at 60°. It consists of 32 soda + 32 sulphurous acid. The crystals contain twelve proportionals of water = 108.

590. *Sulphate of Soda—Glauber's Salt—Sal mirabile*—is abundantly produced in the manufacture of muriatic acid, by the action of sulphuric acid upon common salt.

Common salt consists of 24 Sodium + 36 chlorine. Sulphuric acid consists of 40 dry acid + 9 water. The water of the acid, consisting of 1 hydrogen + 8 oxygen, is decomposed. Its hydrogen is transfered to the chlorine to produce gaseous muriatic acid (1 H. + 36 C. = 37 Mur. A.), and its oxygen unites to the sodium, forming dry soda (8 Ox. + 24 S. = 32 soda). The 40 dry acid, unite to the 32 soda, to produce sulphate of soda, which will be represented by the number 72.

591. Sulphate of soda crystallizes from its aqueous solution in large four-sided prisms, transparent, and efflorescent, when exposed to air. They consist of 72 dry sulphate + 90 water exposed to dry air, the crystals part with about 50 per cent. of water.

The taste of sulphate of soda is saline and bitter: it is soluble in rather less than three times its weight of water at 60°. When exposed to heat it undergoes watery fusion, that is, it melts in its own water of crystallization; when this has evaporated it fuses.

592. Sulphate of soda is sometimes decomposed for the purpose of obtaining soda, by igniting it with chalk and charcoal, or with iron and charcoal. (Of these processes a full account is given in AIKIN's *Dictionary*, Art. *Muriate of Soda.*) Its principal use is in Pharmacy.

593. *Bi-sulphate of Soda* is obtained by adding sulphuric acid to a hot solution of sulphate of soda. It crystallizes in Rhomboids soluble in twice their weight of water at 60°. This salt consists of 72 sulphate of soda + 40 sulphuric acid = 112.—CRELL's *Annals*, 1796.

594. *Ammonio-sulphate of Soda* is a triple salt, formed by saturating the bi-sulphate with ammonia.—CRELL's *Annals*, 1796, I.

595. *Phosphite of Soda* has not been examined. *Hypophosphite of Soda* is very soluble both in alcohol and water.—*Annales de Chim. et Phys.* ii. 142.

596. *Phosphate of Soda* crystallizes in rhomboidal prisms soluble in four parts of water at 60°, and efflorescing when exposed. It has a pure saline taste. It consists of

32 soda
28 phosphoric acid
——
60

The crystals contain about 60 per cent. of water. This salt is usually obtained for pharmaceutical purposes by saturating the impure phosphoric acid, obtained from calcined bones by sulphuric acid, (See *Phosphorus*) with carbonate of soda: the liquor is filtered, evaporated, and set aside to crystallize. It was introduced into pharmacy by Dr. Pearson; it is the *sal perlatum* of some old writers.

When heated, phosphate of soda fuses and boils up, and having lost its water of crystallization, it runs into a clear glass, which becomes opaque on cooling. If a globule be heated before the blow-pipe it assumes the dodecaëdral figure as it cools.

597. Treated with sulphuric acid, phosphate of soda is only partly decomposed, a *bi-phosphate of Soda* being formed, which is more soluble than, and not so easily crystallizable as the phosphate.

598. *Ammonio-phosphate of Soda* exists in human urine, whence it was procured by the early chemists under the names of *microcosmic* and *fusible salt*. When exposed to heat the ammonia is expelled, and a *bi-phospate of soda* remains: it appears to consist of two proportionals of phosphoric acid = 56; one of soda = 32, and one of ammonia = 17. —FOURCROY, *Annales de Chimie*, vii. 183.

599. *Carbonate of Soda* is chiefly obtained by the combustion of marine plants, the ashes of which afford, by lixiviation, the impure alcali called *soda*. Two kinds of rough soda occur in the market; *barilla*, and *kelp*; besides which, some *native carbonate of soda* is also imported. Barilla is the semifused ash of the *salsola soda*, which is largely cultivated upon the Mediterranean shore of Spain, in the vicinity of Alicant. Kelp consists of the ashes of sea weeds, which are collected upon many of the rocky coasts of Britain, and burned in kilns, or merely in excavations made in the ground and surrounded by stones. It seldom contains more than 5 per cent. of carbonated alcali, and about 24 tons of sea weed are required to produce one ton of kelp. The best produce is from the hardest *fuci*, such as the *serratus*, *digitatus*, *nodosus*, and *vesiculosus*. (MAC CULLOCH's *Western Islands*, Vol. i., p. 122.) The rough alcali is contaminated by common salt, and other impurities, from which it may be separated by solution in a small portion of water, filtrating the solution, and evaporating it at a low heat: the common salt may be skimmed off as its crystals form upon the surface.

600. The primitive crystalline form of carbonate of soda is an octoëdron, with a rhombic base; the solid angles of the summit are always wanting, being replaced by planes parallel to the base, and thus presenting a solid with 10 surfaces. It is soluble in twice its weight of water at 60°. Its taste is strongly alcaline, and it greens vegetable blues. It consists of

32 soda
22 carbonic acid.
——
54

Its crystals contain seven proportionals of water = 63, which may be expelled by heat. They effloresce by exposure to air. This salt is the *Sodæ-Subcarbonas* of the *Pharmacopœia*.

In the analysis of barilla and kelp, to ascertain the relative proportion of soda, it may be useful to know that 100 parts of dilute nitric acid, specific gravity 1.36, will saturate 50 parts of dry carbonate of soda, which are equivalent to about 29 of pure soda.

601. *Bi-carbonate of Soda* is formed by passing carbonic acid through the solution of the subcarbonate. By evaporation a crystalline mass is obtained. This salt consists of

32	soda
44	carbonic acid
76	

The bi-carbonate of soda has a very slightly alcaline taste, and it is much less soluble in water than the sub-carbonate.

602. This salt, as well as the bi-carbonate of potassa, may be obtained by treating their respective carbonates with carbonate of ammonia; pure ammonia is evolved and bi-carbonates are formed.—See *London Pharmacopœia.*

In the manufacture of this bi-carbonate for the purpose of commerce, 160 lbs. of carbonate may be dissolved in 13 gallons of water, and carbonic acid thrown into the solution in a proper apparatus. The bi-carbonate falls as it forms to the amount of about 50 lbs., and being separated from the solution may be conveniently dried by pressure in an hydraulic press, and subsequent exposure to heat not exceeding 100°. A fresh portion of carbonate is dissolved in the mother liquor, and the operation repeated as before.

603. A mixture of the carbonates of soda occurs native in great abundance in Africa, in the province of Gahena, near Fezzan. The natives call it *Trona.* It has been analyzed by Mr. R. Phillips, who considers it as a compound intermediate between the carbonate and bi-carbonate, composed of 3 proportionals of acid and 2 of base, or 1 soda + 1½ acid; hence he terms it a *sesqui-carbonate of Soda.*—*Quarterly Journal*, vii., p. 298.

A very productive soda-lake also exists in South America in Maracaybo, one of the provinces of Venezuela.—*Quarterly Journal*, i. p. 188.

604. *Subborate of Soda—Borax.*—This salt, which has been very long known, is imported from India in an impure state, under the name of *Tincal*, which, when purified, is called *Borax.* It crystallizes in irregular hexaedral prisms, slightly efflorescent. Its taste is alcaline and styptic. It is soluble in 20 parts of water at 60°, and in six parts of boiling water. When heated it loses water of crystallization, and becomes a porous friable mass, called *calcined borax.* It consists, according to Bergman, of

34	acid
17	soda
49	water
100	

Sulphuric acid decomposes this salt, producing sulphate of soda and boracic acid. (Chap. IV. § vi.) It has a place in the *Pharmacopœia*, and is sometimes used as a flux.

605. The salts of sodium are soluble in water. They are not pre-

cipitated either by pure or carbonated alcalis, or hydrosulphuret of ammonia, or ferro-prussiate of potassa; they produce no precipitate in solution of muriate of platinum, and do not convert sulphate of alumina into octoëdral alum.

606. Potassium and sodium form an alloy, which, if composed of one part of potassium and three of sodium, remains fluid at 32°. Equal parts of the metals form a brittle crystallizable alloy.

SECTION III. *Lithium.*

607. In the analysis of a mineral, called *petalite*, M. Arfwedson discovered about three *per cent.* of an alcaline substance, which was at first supposed to be soda; but, finding that it required for its neutralization a much larger quantity of acid than soda, he was led to doubt its identity with that alcali, and the further prosecution of his inquiries fully demonstrated that it possessed peculiar properties. The mineral called *triphane*, or *spodumene*, also affords the same substance, to which the term *lithia*, deduced from its lapideous original, has been applied. It has also been detected in a few other minerals.

The following is the mode of obtaining lithia from the above substances:—Reduce the mineral to a fine powder, and fuse it with about half its weight of potassa; dissolve the fused mass in muriatic acid, filter, and evaporate to dryness; digest the dry mass in alcohol; the only substance present, soluble in that liquid, is the *muriate of lithia*, which is taken up, and by a second solution and evaporation is obtained pure. It may be decomposed by digesting carbonate of silver in its aqueous solution, by which a carbonate of lithia is formed, decomposible by lime, in the way of the other alcaline carbonates.

608. When lithia is submitted to the action of the Voltaic pile, it is decomposed with the same phænomena as potassa and soda; a brilliant white and highly combustible metallic substance is separated, which may be called *lithium*, the term *lithia* being applied to its oxide.

The properties of this metal have not hitherto been investigated, in consequence of the difficulty of procuring any quantity of its oxide.

609. Pure lithia is very soluble in water, and its solution tastes acrid like the other fixed alcalis. It acts powerfully on vegetable blues, converting them to green. It is very sparingly soluble in alcohol.

Direct experiments upon the composition of lithia are yet wanting. By calculation from the composition of the sulphate, as analyzed by Vauquelin, it would appear to contain about 55.2 lithium + 44.8 oxygen.*

610. *Chloride of Lithium*, obtained by evaporating the muriate to dryness, and fusing it, is a white semitransparent substance. It evidently differs from the chlorides of potassium and sodium, in being extremely deliquescent; in being soluble in alcohol; in being decompos-

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* $\overset{\text{oxygen}}{44.8} : \overline{55.2 + 44.8} = \overset{\text{lithia}}{100} :: 8$ (atom oxygen) : 17.8 (the atom lithia which agrees with the composition of the sulphate.

ed when strongly heated in the open air, when it loses chlorine, absorbs oxygen, and becomes highly alcaline; in being very difficultly crystallizable; and in tinging the flame of alcohol of a red colour.

611. *Iodide of Lithium.*—The action of iodine, of hydriodic acid, and of iodic acid, on lithia has not been examined.

612. *Nitrate of Lithia* is a very soluble deliquescent salt, fusible and decomposed by heat; its taste is cooling; it crystallizes in rhomboids.

613. *Sulphuret of Lithium.*—The action of sulphur on lithium and lithia appears analogous to its action on potassium and potassa, but the compounds have not been precisely examined.

614. *Sulphate of Lithia* crystallizes in small rectangular prisms, perfectly white, and possessed of much lustre. Their taste is saline, and their solubility intermediate between that of sulphate of potassa and sulphate of soda. The crystals contain no water, and fuse at a heat below redness. Their solution occasions no change in solution of platinum, nor in tartaric acid. They consist of

Sulphuric acid	69.18	or	40
Lithia	30.82	or	17.8
	100	or	57.8

615. *Phosphate of Lithia* has been examined by Dr. Gmelin: it may be obtained by adding phosphoric acid to sulphate of lithia; no precipitate is at first formed, but on adding excess of ammonia, an insoluble phosphate of lithia falls. This property enables us to separate lithia from potassa and soda. The phosphate of lithia may be decomposed by dissolving it in acetic acid and adding acetate of lead: *acetate of lithia* remains in solution.

616. *Carbonate of Lithia.*—When a strong solution of carbonate of potassa is added to sulphate of lithia, a white precipitate of *carbonate of lithia* is formed. It requires about 100 parts of water at 60° for its solution. It is fusible, alcaline, effervesces with acids, and absorbs carbonic acid from the air. Lithia and its carbonate, when heated upon platinum, act upon that metal.

617. If we assume from Vauquelin's corrected analysis of the sulphate, that lithia contains 45 per cent. of oxygen and 55 of lithium, and that it is a protoxide, then 45 : 55 : : 8 : 9.77. So that the number 9.8 might be assumed as the representative number of lithium; and oxide of lithium, or lithia, would contain—

Lithium	9.8	+	Oxygen	8	=	17.8
Chloride of Lithium	9.8	+	Chlorine	36	=	45.8
Nitrate of Lithia—Lithia . .	17.8	+	Nitric acid	54	=	71.8
Sulphate	17.8	+	Sulphuric acid . .	40	=	57.8
Carbonate	17.8	+	Carbonic acid . .	22	=	39.8

N. B. It is probable that 10 is the number for lithium instead of 9.8, for 10 is a multiple of 0.125 (the atom hydrogen) which is not the case with 9.8.

SECTION IV. *Calcium.*

618. WHEN lime is electrized negatively in contact with mercury, an amalgam is obtained. which, by distillation, affords a white metal. It has been called *calcium*, and when exposed to air, and gently heated, it burns and produces the *oxide of calcium*, or *lime*.

Lime appears to consist of 20 parts of this metallic base united to 8 parts of oxygen, so that its representative number will be = 28.

619. The combinations of lime are very abundant natural products, and of these the *native carbonate* which, more or less pure, constitutes the different kinds of marble, chalk, and limestone, and which is also the leading hardening principle of shell, coral, &c., may be considered as the most important.

Lime may be obtained in a state of considerable purity by exposing powdered white marble to a white heat, which expels the carbonic acid. To obtain absolutely pure lime, white marble may be dissolved in dilute muriatic acid, a little ammonia added to the solution, and filtered: carbonate of ammonia is then added, and the precipitate dried, washed, and exposed to a white heat. Its colour is light grey; it is acrid and caustic and converts vegetable blues to green; its specific gravity is 2.3; it is very difficult of fusion, but remarkably promotes the fusion of most other earthy bodies, and is therefore used in several metallurgic processes as a cheap and powerful flux. When quite pure it can only be fused in very minute particles by the oxygen blow-pipe, or by the Voltaic flame. It is an essential ingredient in mortar and other cements used in building. Exposed to air it becomes white by the absorption of water and a little carbonic acid.

620. When a small quantity of water is poured upon lime, there is a great rise of temperature resulting from the solidification of a portion of the water, and a white powder is obtained, called *slacked lime*, which is a *hydrate*, and which appears to consist of one proportional of water = 9 + one proportional of lime = 28 = 37 hydrate.

Lime may be obtained in a crystalline form by placing lime water under the receiver of an air-pump, containing another vessel of sulphuric acid. The water is thus slowly evaporated, and imperfect six-sided crystals of hydrate of lime are formed.—GAY-LUSSAC, *Annales de Chimie et Phys.*, i. 334.

At the temperature of 60°, 750 parts of water are required for the solution of one part of lime.

621. Lime-water is limpid and colourless; its taste is nauseous, acrid, and alcaline, and it converts vegetable blues to green. It is usually prepared by pouring warm water upon powdered lime, and allowing the mixture to cool in a close vessel: the clear part is then decanted from the remaining undissolved portion of lime. When lime-water is exposed to the air, a pellicle of carbonate of lime forms upon its surface, which, if broken, is succeeded by others, until the whole of the lime is thus separated in the form of an insoluble carbonate. Lime-water is used in medicine as an antacid.

622. When oxygen is passed over heated lime, it is absorbed, and a portion of *peroxide of calcium* is formed. A hydrated peroxide of cal-

cium is thrown down, according to M. Thenard, when lime-water is dropped into oxygenated water.

623. *Chloride of Calcium* is produced by heating lime in chlorine, in which case oxygen is evolved; or by evaporating *muriate of lime*, obtained by dissolving carbonate of lime in muriatic acid, to dryness, and exposing the dry mass to a red heat in close vessels. It consists of 20 calcium + 36 chlorine = 56. This compound has a strong attraction for water; it deliquesces when exposed to air, and becomes what used to be called *oil of lime*. It is difficultly crystallizable from its aqueous solutions; with care, however, it may be obtained in six-sided prisms, consisting of the chloride combined with water. It is most readily crystallized by exposing its solution to the temperature of 32°. Its taste is bitter and acrid; one part of water at 60° dissolves four parts of the chloride. Its solubility, however, is greatly influenced by temperature, for at 32° one part of water will not dissolve more than two of the salt, and at 212° it takes up nearly any quantity. It is copiously soluble in alcohol, and much heat is evolved during the solution. When fused it acquires a phosphorescent property, as was first observed by Homberg, and hence termed *Homberg's phosphorus*. It is abundantly produced in the manufacture of carbonate of ammonia, from the decomposition of muriate of ammonia by lime, and hence has sometimes been called *fixed sal ammoniac*. The production of cold by mixing muriate of lime with snow has already been adverted to. (81.) Chloride of lime absorbs ammoniacal gas in considerable quantities. (FARADAY, *Journal of Science*, Vol. v. p. 74.) In its fused state this compound is very useful for drying certain gaseous bodies, but where the quantity of the gas is to be ascertained, its powers of absorption in certain cases must not be overlooked.

Pelletier has stated, that if carbonic acid be passed through a solution of muriate of lime, the whole becomes a hard solid mass. If sulphuric acid be poured into a strong solution of muriate of lime, the whole congeals into a solid mass of sulphate of lime.

624. A substance called *Oxymuriate of Lime* is abundantly employed as a bleaching material, and manufactured by passing chlorine into leaden chambers containing hydrate of lime in fine powder, by which the gas is copiously absorbed. Dr. Thomson has shown this to be a compound of chlorine and lime; when heated it gives off a large quantity of oxygen, and a chloride of calcium results. This shows the superior attraction of calcium for chlorine compared to oxygen, the latter being expelled from the lime.

625. *Chlorate of Lime* is a very soluble deliquescent salt of a sharp bitterish taste. It is most easily produced by dissolving carbonate of lime in chloric acid. Exposed to heat, oxygen is evolved, and a chloride formed.

626. *Iodate of Lime* is difficultly crystallizable in small quadrangular prisms. *Hydriodate of Lime* is very deliquescent; when dried it becomes *iodide of calcium*, a white fusible compound.

627. *Nitrate of Lime* is a deliquescent salt, soluble in 4 parts of water at 60°. It is found in old plaster and mortar, from the washings

of which, nitre is procured by the addition of carbonate of potassa. It is composed of

34.94	Lime	28
65.06	Nitric acid	54
100		82

The production of this salt in artificial nitre-beds has already been adverted to. (551.) It may be crystallized in six-sided prisms. It is soluble in alcohol. When exposed to a moderate heat it undergoes watery fusion: the water then evaporates, and the salt fuses; on cooling it concretes into a semi-transparent phosphorescent substance, called from the discoverer of this property, *Baldwin's phosphorus*. At a red heat it is decomposed; its acid is dissipated, and pure lime remains. It contains in its crystallized state about 25 per cent. of water, and may hence be considered as composed of

1	proportional dry nitrate	82
3	——— water	27
		109

628. *Sulphuret of Lime* is formed by heating lime with sulphur. It is soluble in water with the same phænomena as sulphuret of potassa.

629. According to Mr. Herschel, crystallized *hydrosulphuret of lime* is formed when three parts of slacked lime and one of sulphur are boiled in twenty parts of water, and the solution allowed to cool upon the sediment: he dried the crystals by exposure to the absorbent power of a large surface of sulphuric acid, placed under an exhausted receiver. Their form is that of quadrilateral prisms with dihedral summits. They are sparingly soluble in cold water, the solution having a yellow colour and an acrid, bitter, and sulphurous taste. They consist of two proportionals of lime, two of sulphur, one of hydrogen, and four of water.—*Edinburgh Philosophical Journal*, i. p. 11, *&c*.

630. When sulphurous acid is ground in a mortar with the above crystals its smell disappears, and when filtered it is found to be a solution of *hyposulphite of lime*. By passing sulphurous acid through an aqueous solution of sulphuret of lime, the same product is obtained: and if the solution be filtered and evaporated, at a temperature not exceeding 140°, it furnishes crystals: the temperature of ebullition decomposes it. The crystals are little altered by air, very soluble in water, and insoluble in alcohol. They consist, according to Mr. Herschel, of

Lime	21.71
Acid	36.71
Water	41.58
	100

631. The hyposulphites of soda, potassa, and ammonia, of baryta, and of strontia, may be formed by passing sulphurous acid through the aqueous solutions of their sulphurets.

632. *Sulphite of Lime* is formed by passing sulphurous acid into a mixture of lime and warm water. It is a white powder, soluble by excess of sulphurous acid, and then separating in prismatic crystals, of difficult solubility, efflorescent, and passing into sulphate of lime by exposure to air.

633. *Sulphate of Lime* occurs native in selenite, gypsum, and plaster-stone. It is easily formed artificially, and then affords silky crystals soluble in 350 parts of water. When these, or the native crystallized sulphate are exposed to a red heat, they lose water, and fall into a white powder (*plaster of Paris*), which, made into a paste with water, soon solidifies. Dry sulphate of lime consists of

28 lime
40 sulph. acid
—
68

Crystalline sulphate of lime contains two proportionals of water, and is consequently represented by 68 + 18 = 86. As sulphate of lime is more soluble in water than pure lime, sulphuric acid affords no precipitate when added to lime-water. Nearly all spring and river water contains this salt, and in those waters which are called *hard* it is abundant. It gives to them a slightly nauseous taste. At a very high temperature sulphate of lime is fusible, but it suffers no decomposition; heated with charcoal it is converted into a sulphuret. It dissolves without decomposition in dilute nitric and muriatic acids, and separates from these solutions when concentrated in long silky or transparent crystals. It is decomposed by the alcaline carbonates.

634. *Native Sulphate of Lime* occurs in various forms. The crystallized variety is usually called *selenite*; the fibrous and earthy, *gypsum*; and the granular or massive, *alabaster*. The primitive form of selenite is a rhomboidal prism of 113° 8′ and 66° 52′. The crystals are commonly transparent, and of various colours; it is softer than native carbonate of lime, and yields very easily to the nail. It is seldom found in veins, but generally disseminated in argillaceous strata. It occurs in Cumberland at Alston, and in Oxfordshire at Shotover Hill, where it is often accompanied by shells and pyrites, and appears to have resulted from their mutual decomposition. A beautiful fibrous variety is found in Derbyshire, applicable to ornamental purposes.

Massive and granular gypsum is found in this country accompanying the salt-deposits in Cheshire. It abounds at Montmartre, near Paris, and contains organic remains; sometimes it forms entire hills. In the Tyrolese, Swiss, and Italian Alps, it is found upon the primitive rocks, often of the purest white, especially at Montier, near Montblanc, and near the summit of Mount Cenis. It is turned by the lathe, and sculptured into a variety of beautiful forms, more especially by the Florentine artists.

635. There is a variety of sulphate of lime, which has been called *anhydrous gypsum*, or *anhydrite*, in reference to its containing no water. It is harder than selenite, and sometimes contains common salt, and is then called *muriacite*. It is rarely crystallized, generally massive and lamellar, and susceptible of division into rectangular prisms. It has been found in Derbyshire and Nottinghamshire of a pale blue tint;

sometimes it is pink or reddish, and often white. It has been found at Vulpino, in Italy, and hence called *Vulpinite.* The statuaries of Bergamo and Milan employ it, and artists know it by the name of *Marbre di Bergamo.* A compound of sulphate of lime and sulphate of soda is found in the salt-mines of New Castile, which mineralogists have described under the name of *Glauberite.*

636. *Phosphuret of Lime.*—By passing phosphorus over red-hot lime, a brown compound is produced, which rapidly decomposes water with the evolution of phosphuretted hydrogen gas. *Hydrophosphuret* and *hypo-phosphite of lime* are also formed.

The best process for obtaining this phosphuret is the following: select a green glass, or porcelain tube, closed at one end, and about 18 inches long, and one inch diameter, and carefully cover it with a clay lute containing a very little borax. Put an ounce of phosphorus broken into small pieces into the lower end, and fill it up with pieces of clean quicklime, about the size of large peas: place it in an inclined position in a furnace, so that the end containing the phosphorus may protrude, while the upper part of the tube is heating to redness; then slowly draw the cool part into the fire, by which the phosphorus will be volatilized, and passing into the red-hot lime, convert a portion of it into phosphuret. Care should be taken that no considerable portion of phosphorus escapes and burns away at the open end of the tube, which, after the process, should be corked and suffered to cool. Its contents may then be shaken upon a sheet of paper, and the brown pieces picked out and carefully preserved in a well stopped phial; the white pieces, or those which are only pale brown, must be rejected. This compound, though called phosphuret of lime, is probably a *phosphuret of calcium.*

637. Neither the *Phosphite* nor *Hypophosphite of Lime* have been particularly examined.

638. *Phosphate of Lime* exsits abundantly in the bones of animals; it is also found in the mineral world. It may be formed artificially, by mixing solutions of phosphate of soda and muriate of lime. It is insipid and insoluble in water, but dissolves in dilute nitric and muriatic acid without decomposition, and is precipitated unaltered by caustic ammonia. It is decomposed by sulphuric acid, and thus the phosphoric acid for the production of phosphorus is usually procured. (See PHOSPHORUS, Chap. IV., Sect. iv.) It consists of

28	lime
28	phosphoric acid
56	

At a very high temperature phosphate of lime fuses into an opaque white enamel.

639. *Bi-phosphate of Lime* is formed by digesting the phosphate in phosphoric acid. On evaporation a white deliquescent uncrystallizable mass is obtained, composed of one proportional of lime + two of phosphoric acid.

640. The phosphoric glass described under the head *phosphoric acid* (Chap. IV., Sect. iv.) is considered by Dr. Thomson as a definite compound, which he has termed *quadriphosphate of lime.*—*System*, ii. 460.

641. *Native Phosphate of Lime* has by some been regarded as a *sub-phosphate*, in which case it would be composed of two proportionals of of lime + one phosphoric acid. This compound occurs crystallized and massive, and is known under the names of *apatite*, *asparagus-stone*, and *phosphorite*. The crystallized variety is found in Cornwall and Devonshire, of singular beauty. Its primitive form is a six-sided prism: it also occurs in volcanic products; and, what is curious, the former is phosphorescent and the latter not. The massive variety is found in Bohemia and in Spain.

642. *Carbonate of Lime* is the most abundant compound of this earth. When lime-water is exposed to air, it becomes covered with an insoluble film of carbonate of lime, and hence is an excellent test of the presence of carbonic acid. But excess of carbonic acid re-dissolves the precipitate, producing a super-carbonate. Carbonate of lime is precipitated by the carbonated alcalis from solutions of muriate, nitrate, and sulphate of lime. Exposed to a red heat the carbonic acid escapes, and quicklime is obtained. It consists of

28 lime
22 carbonic acid
—
50

643. Carbonate of lime occurs in nature in great abundance and in various forms. The primitive form of crystallized carbonate of lime, or *calcareous spar*, is an obtuse rhomboid of 105° 5′ and 74° 55′. Its specific gravity is 2.7. It occurs in every kind of rock, and its secondary forms are more numerous than those of any other substance; sometimes it forms fine *stalactites*, of which some of the caverns of Derbyshire furnish magnificent specimens; it is here deposited from its solution in water acidulated by the carbonic acid, and substances immersed in this water become incrusted by carbonate of lime, when the excess of acid flies off, as seen in the *petrifying well of Matlock*. A fibrous variety of carbonate of lime, called *satin spar*, is found in Cumberland.

Another variety, originally found in Arragon in Spain, has been termed *Arragonite*; it occurs in six-sided crystals, of a reddish colour, and harder than the common carbonate. There is an acicular, or fibrous variety, found in France and Germany; and the white radiated substance, improperly called *flos ferri*, is also regarded as of the same species. Some varieties contain about 3 *per cent.* of strontia.

All the varieties of marble and lime-stone consist essentially of carbonate of lime; of these, *white granular lime-stone*, or *primitive marble*, is most esteemed; there are, also, many coloured varieties of extreme beauty. It is distinguished from *secondary lime-stone* by the abscence of all organic remains, by its granularly foliated structure, and by its association with other primitive substances.

The most celebrated statuary marble is that of Paros and of Mons Pentelicus, near Athens: of these, some of the finest specimens of ancient sculpture are composed. The marble of Carrara, or Luni, on the eastern coast of the Gulf of Genoa, is also much esteemed; it is milk-white, and less crystalline than the Parian.

Many beautiful marbles for ornamental purposes are quarried in Derbyshire, and especially the black marble, called also *Lucullite*.

Westmoreland and Devonshire also afford beautiful varieties, and in Anglesea, a marble intermixed with green serpentine is found, little inferior in beauty to the *verd antique*.

Among the inferior lime-stones, we enumerate many varieties, such as *common marble*; *bituminous lime-stone*, abundant upon the Avon, near Bristol, and known under the name of *swine-stone* or *stink-stone*, from the peculiar smell which it affords when rubbed: *Oolite* or *Roestone*, of which the houses of Bath are built; and its variety, called *Portland stone*: *Pisolite* consists of small rounded masses, composed of concentric layers, with a grain of sand always in the centre: and, lastly, *chalk* and *marl*.

All these substances are more or less useful for ornamental purposes, or for building; they afford quicklime when burned, and in that state are of great importance as manures, and as ingredients in the cements used for building. There is a great variety of lime-stones used for burning into *quicklime*, and, generally speaking, any of the varieties may be used which neither fuse nor crumble into powder at the temperature required to expel the carbonic acid, which is a full red heat.

644. *Borate of Lime* is a white tasteless powder of very difficult solubility in water.

645. The salts of lime have the following properties:—

Those which are soluble are not altered by pure ammonia, but they are decomposed by potassa and soda. They are also decomposed by the carbonates of potassa, soda, and ammonia, which produce precipitates of carbonate of lime.

Oxalate of ammonia produces in their solutions a white insoluble precipitate of oxalate of lime, which, exposed to a red heat, affords pure lime.

The insoluble salts of lime are decomposed by being boiled with carbonate of potassa, and afford carbonate of lime.

646. *Fluor Spar—Fluate of Lime.*—These terms have been applied to a body containing a peculiar principle which has not hitherto been obtained in an insulated state.

It is a principle which probably belongs to the acidifying electro-negative supporters of combustion, and which in fluor spar is, perhaps, united to calcium. It appears to be united with hydrogen in the *fluoric* or *hydrofluoric* acid. This supposed base has been called *fluorine* by Sir H. Davy; and *phtore* (from φθόριος, *destructive*,) by M. Ampére.

647. Fluor Spar is a mineral found in many parts of the world, but in great beauty and abundance in England, and especially in Derbyshire. Here it is commonly called *Derbyshire spar*, or by the miners of that county *blue John*. It is usually found in cubic crystals, which may easily be cleaved into octoëdra, sometimes considered as its primitive form (27). Its colours are extremely various. Its specific gravity 3. It phosphoresces when exposed to a heat a little below redness. It generally occurs in veins; in the Odin mine at Castleton in Derbyshire, it is found in detached masses, from an inch to more than a foot in thickness; their structure is divergent, and the colours, which are various, disposed in concentric bands. It is the only variety which admits of being turned in the lathe into vases and other ornamental articles.

Compact fluor is a scarce variety: the finest specimens come from the Hartz. A third variety is *chlorophane*, so called from the beautiful pale green light which it exhibits when heated.

The nature of the colouring matter of fluor spar is not exactly understood. It is liable to fade, and the blue varieties become red and brown by heat.

618. *Hydrofluoric acid* (*hydrophtoric* of Ampere) is procured by distilling a mixture of one part of the purest fluor spar in fine powder, with two of sulphuric acid; the distillatory apparatus and receiver should be of lead or silver, for glass is instantly acted on; the heat required is not considerable; sulphate of lime remains in the retort, and a highly acrid and corrosive liquid passes over, which requires the assistance of ice for its condensation.

This acid is colourless, of a very pungent smell, and extremely destructive. If applied to the skin it instantly kills the part, producing extreme pain, and extensive ulceration. At 80° it becomes gaseous; it has never been frozen; it produces white fumes when exposed to a moist air, and occasions a hissing noise when dropped into water.

This acid acts upon potassium and sodium, and some other metals, with great energy; hydrogen is evolved, and a peculiar compound, probably of the basis of the acid, and the metal, results. These compounds might be called *fluorides*. The principal *hydrofluates*, or *fluates*, have been examined by Gay-Lussac and Thenard. (*Recherches Physico-chimiques.*) They have not been analyzed, but if we adopt the number 17 as the representative of the acid, considering it as composed of 16 fluorine + 1 hydrogen, it is probable that they consist of one proportional of acid and one of base.

619. *Hydrofluate of Ammonia* is not crystallizable, and when evaporated loses a portion of alcali and becomes sour; when heated it rises in a dense white vapour.

620. *Hydrofluate of Potassa* is a very soluble deliquescent, and difficultly crystallizable salt, of a sharp taste. When heated it first loses its water of crystallization, then fuses (becoming *fluoride of potassium ?*) Sulphuric acid separates the hydrofluoric.

621. *Hydrofluate of Soda* has less taste, and is less soluble than the preceding. When heated it decrepitates then fuses. It is permanent in the air, and separates from its solution in hot water, partly as a transparent pellicle and partly in crystals.

622. When hydrofluoric acid is poured into solutions of the salts of lime, a white insoluble powder is thrown down, which resembles fluor spar in its chemical properties, and must therefore be considered as a *fluoride of calcium.*

623. The hydrofluoric is the only acid that acts rapidly on glass, and cannot therefore be preserved in vessels of that material. If a plate of glass, covered with wax, having any device traced upon it by a blunt graver, be exposed to the fumes of this acid, the glass presents the appearance of having been etched, upon removing the wax.—See *Silicated fluoric Acid*, Sect. xxxvii.

624. *Fluoboric Acid.*—This is probably a compound of fluorine with boron, and if regarded as consisting of one proportional of each of its components, its representative number will be 22, and it will contain 16 fluorine + 6 boron. It is gaseous, and may be obtained by heating in a glass retort twelve parts of sulphuric acid, with a mixture of one part of fused boracic acid and two of fluor spar, reduced to a very fine powder. The gas must be received over mercury: 100 cubical inches weigh 72.5 grains; so that the specific gravity of fluo-

boric acid compared with hydrogen, is 32.22, and with atmospheric air, 2.400.* It produces very copious fumes when suffered to escape into a moist atmosphere; when acted upon by water, which dissolves 700 times its volume, it affords a solution of hydrofluoric and boracic acids, whence it would seem that the hydrogen is transferred to the fluorine, and the oxygen to the boron. It acts with great energy on vegetable and animal bodies, depriving them of moisture and hydrogen. A piece of paper introduced into fluoboric gas becomes instantly charred. Potassium heated in this gas occasions the deposition of boron, and the production of fluoride of potassium, which by the action of water becomes hydrofluate of potassa.

625. The fluoboric acid combines with different basis, and produces a class of salts which have been called *fluoborates*: of these the *fluoborate of ammonia* has been examined by Dr. John Davy. (*Phil. Trans.* 1812.) It appears from his experiments that the fluoboric acid is capable of condensing successively, one, two, and three volumes of ammonia. The first is a white solid, volatile in close vessels by the application of a gentle heat. The two other compounds are liquid, and when exposed to the atmosphere, lose ammonia and pass into the first.

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SECTION V. *Barium.*

626. To obtain this metal, the earth baryta is negatively electrized in contact with mercury; an amalgam is gradually formed, from which the mercury may be expelled by heat, and the metal barium remains; appearing, according to Sir H. Davy, of a dark grey colour, and being more than twice as heavy as water. It greedily absorbs oxygen, and burns with a deep red light when gently heated, producing the oxide of barium.

627. *Oxide of Barium, Baryta*, or *Barya*, is obtained by exposing the crystals of nitrate of baryta for some time to a bright red heat. It is of a grey colour, and very difficult of fusion; it appears to consist of 70 barium + 8 oxygen, and is, consequently, represented by 78. Its specific gravity is about 4, hence the name *Baryta*, as being the heaviest of the substances usually called earths. It eagerly absorbs water, heat is evolved, and a white solid is formed, containing about 10 per cent. of water, which it retains at a red heat; this is the *hydrate of baryta*, and may be considered as a compound of 1 proportional of baryta = 78 + 1 proportional of water = 9, and is, consequently, represented by 87.

628. *Hydrate of Baryta* dissolves in boiling water, and, as the solution cools, deposits flattened hexagonal prisms, which contain a larger quantity of water, and are easily fusible. According to Mr. Dalton, crystallized baryta consists of 1 proportional of baryta and 20 of wa-

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* Thomson in his late experiment (ann. Phi. vol. 16, 1820) makes the specific gravity compared with atmospheric air = 2.3694, this would make the specific gravity about 34 times that of hydrogen.

ter; if it be exposed to air it effloresces into a white powder, containing 1 proportional of baryta and 5 of water; it appears therefore that there are three hydrates of baryta. (*New Chem. Phil.*, ii. 522.) The aqueous solution, or *baryta water*, is limpid, colourless, and acts energetically on vegetable blues and yellows, changing them to green and red; it rapidly absorbs carbonic acid, and deposits an insoluble carbonate of baryta. As baryta, like the alcalis, converts vegetable blues to green, and serves as an intermede between oil and water, it has been called an *alcaline earth*. It has a very acrid caustic taste, and is highly poisonous. It exists in two natural combinations only, namely, as sulphate and carbonate.

629. When baryta is heated in oxygen, or when oxygen is passed over baryta heated to redness in a glass tube, the gas is absorbed and a grey compound is obtained, which is the *peroxide of barium*; consisting of

1 proportional of barium = 70
2 ———————— oxygen = 16
—
86

630. By dissolving peroxide of barium in muriatic acid, and precipitating by sulphuric acid, M. Thenard succeeded in obtaining a new and singular compound of oxygen and water to which the term *peroxide of hydrogen* may be applied. The solution of the peroxide of barium, and the subsequent separation of the protoxide is repeated a sufficient number of times, in the same portion of dilute muriatic acid; sulphate of silver is then added to separate the muriatic acid, and the sulphuric, which then becomes its substitute, is ultimately removed by baryta. M. Thenard, in his elaborate essay upon this new compound, has shown that the process, although in theory sufficiently simple, presents many practical difficulties, chiefly arising from the impurities contained in the peroxide of barium. To obtain this substance pure, upon which the success of the subsequent operations depends, he gives the following directions. Prepare a very pure nitrate of baryta, and decompose it by a strong heat in a porcelain vessel, by which baryta, containing a portion of silica and alumina, but free from manganese, will be obtained; the latter impurity must always be most cautiously avoided, for oxide of manganese possesses the property of energetically decomposing the oxygenated water.

The baryta, broken into small pieces, is then introduced into a luted glass tube (the glass should not contain lead) large enough to contain about two pounds of it, and being heated to dull redness, a current of dry and perfectly pure oxygen gas is passed through it which it rapidly absorbs; this operation is to be continued till the oxygen escapes from a small tube inserted into the opposite extremity of the larger one.

The peroxide thus obtained is pale grey, and frequently some pieces are speckled with green, which announces the presence of manganese, and which should be rejected: its distinctive character is, that it crumbles when a few drops of water are added to it, without producing heat.

The process then proceeds as follows. Take a certain quantity of water (about eight ounces for instance), and add to it a sufficiency of pure and fuming muriatic acid to dissolve about 230 grains of baryta: put this acid liquor into a glass vessel, which during the operation must be surrounded by ice: then take about 185 grains of the peroxide, rub it into a fine paste with a little water in an agate mortar, and put it into the acid liquor with a box-wood spatula; it soon dissolves without effervescence: to this solution add pure sulphuric acid drop by drop, stirring it with a glass rod, till it is in slight excess, which is known by the readiness with which the sulphate falls: then dissolve a second portion of the deutoxide and precipitate as before, taking care to use enough but not too much sulphuric acid. The liquor is now to be filtered, and the residue washed with a little water, so as to keep up the original measure by adding it to the first portion: a second and third washing of the residue with very small quantities of water may be advisable, and these liquors should be kept apart for the purpose of washing the filters in subsequent operations.

A fresh portion of the peroxide is then dissolved in the filtrated liquor and decomposed as before, filtering at every two operations and washing the filter with the savings of the others. We thus proceed till the water is sufficiently oxygenated: when about two pounds of the peroxide have been consumed the water will be united to about thirty times its volume of oxygen, which is as much as it will retain, unless some muriatic acid be added, in which case M. Thenard has made it retain 125 volumes.

When the water is sufficiently oxygenated, it is retained in the ice, and supersaturated with the peroxide of barium, which occasions the separation of flocculi of silica and alumina, coloured with a little oxide of iron and of manganese; the whole is then filtered as quickly as possible, and returned into the vessel surrounded by ice, the baryta is separated by sulphuric acid, and pure sulphate of silver is added to separate the muriatic acid, upon which the liquid, before milky, becomes suddenly clear. The sulphuric acid is ultimately separated by baryta, the liquor filtered and placed in a shallow vessel, under the air-pump receiver, containing a basin of sulphuric acid; the receiver being exhausted, the water evaporates and is absorbed by the acid, while the peroxide of hydrogen being less vaporisable remains; if it give out any oxygen, which sometimes happens from its containing impurities, a drop or two of weak sulphuric acid prevents its further evolution.

The peroxide of hydrogen thus concentrated has the following properties: its specific gravity is 1.45; it is colourless and inodorous; it blisters the cuticle of the tongue, and has a peculiar metallic taste. It does not congeal when exposed to cold, unless diluted. It is rapidly decomposed at a heat below 212°, and very slowly at ordinary temperatures; it may be long kept at 32°. It is decomposed by the pile with the same phænomena as water. It is decomposed by all metals except iron, tin, antimony, and tellurium: the metals should be finely divided, or in powder: silver and oxide of silver decompose it very suddenly with the evolution of heat and light: platinum and gold produce the same phænomena; lead and mercury slowly separate the oxygen. Orpiment and powdered sulphuret of molybdenum act upon it with the same violence as silver; the peroxides of manganese and of lead, also, occasion its instant decomposition.

631. *Chloride of Barium* may be obtained by heating baryta in chlorine, in which case oxygen is evolved: or more easily, by dissolving

carbonate of baryta in diluted muriatic acid. By evaporation, tabular crystals are obtained, soluble in 5 parts of water at 60° ; and consisting, when dry, of 70 barium + 36 chlorine = 106. Its taste is pungent and acrid ; when exposed to heat, the water of crystallization separates, and the dry chloride enters into fusion. It is insoluble in alcohol.

632. *Chlorate of Baryta* is formed in the same way as chlorate of potassa (546). It crystallizes in quadrangular prisms, soluble in four parts of water, at 60°. It consists of

1 proportional of baryta = 78
1 ———— chloric acid = 76
———
154

Or of 1 proportional of barium = 70
6 ———— oxygen = 48
1 ———— chlorine = 36
———
154

Gay-Lussac procured chloric acid (221) by the action of sulphuric acid upon this salt.

633. *Iodide of Barium* is easily formed by acting upon baryta by hydriodic acid, and evaporating the solution. It may also be formed by heating baryta in hydriodic gas ; water and iodide of barium are the results.

634. *Iodate of Baryta* is a very difficultly soluble compound ; the *hydriodate* is crystallizable and very soluble.

635. *Nitrate of Baryta* may be produced by dissolving the native carbonate in nitric acid, evaporating to dryness, re-dissolving, and crystallizing ; it forms permanent octoëdral crystals. Its taste is acrid and astringent. It is soluble in 12 parts of cold and 4 of boiling water ; it is decomposed by a bright red heat, furnishing pure baryta. It consists of

78 baryta
54 nitric acid
———
132

The crystals contain two proportionals of water, or 132 dry nitrate + 18 water.

If a moderately strong solution of the nitrate of baryta be added to nitric acid, a precipitation of nitrate of baryta takes place, in consequence of the abstraction of water by the acid ; hence in using nitrate of baryta as a test of the presence of sulphuric acid in nitric acid, (277) the latter should be considerably diluted previous to its application.

636. *Sulphuret of Barium* is a brown compound, which acts upon water as already described, producing *hydrosulphuret of baryta.*

637. *Hyposulphite of Baryta.*—This salt is thrown down on pouring muriate of baryta into a solution, not too dilute, of hyposulphite of lime ; it is a white powder soluble without decomposition in muriatic acid ; at a low heat it takes fire and the sulphur burns off. When the

solutions from which it is precipitated are dilute, it falls, after some minutes, in small crystalline grains, followed by a copious separation of the salt.—Herschel, *Edinburgh Philosophical Journal*, i. 20.

638. *Sulphite of Baryta* is insoluble in water, and formed by adding sulphite of potassa to muriate of baryta.

639. When sulphurous acid gas is passed into water holding peroxide of manganese in suspension a neutral solution is obtained, composed of sulphate and hyposulphate of manganese. These salts are decomposed by excess of baryta, and a soluble *hyposulphate of baryta* is formed, through which carbonic acid is passed, in order to saturate any excess of baryta; and the whole being heated to drive off carbonic acid which holds a little of the carbonate in solution, the hyposulphate of baryta is obtained, and may be purified by crystallization. The solution of this salt may be decomposed by the careful addition of sulphuric acid, and the *hyposulphuric acid* is thus obtained in solution.

This acid is inodorous, sour, and may be concentrated by exposure to a vacuum with sulphuric acid: it is decomposed by a heat below that of boiling water, sulphurous acid is disengaged, and sulphuric acid remains. It perfectly saturates bases, and forms soluble salts with baryta, strontia, lime, oxide of lead, and probably with all other bases. (*Annales de Chim. et Phys.* x. 312.) The hyposulphate of baryta crystallizes in quadrangular prisms variously terminated; 100 parts of water at 60° dissolve about 14 parts. It consists of

1 proportional of baryta . . . . = 78
1 ———————— hyposulphuric acid = 72
2 ———————— water 9 × 2 . . . . . = 18
168

Or it may be stated as containing in its dry state

1 baryta . . . . . . = 78
Hyposulphuric acid { 1 sulphuric acid = 40
 1 sulphurous acid = 32
150

640. *Sulphate of Baryta* is an abundant natural product; it is insoluble and therefore produced whenever sulphuric acid or a soluble sulphate, is added to any soluble salt of baryta; hence the solutions of baryta are accurate tests of the presence of sulphuric acid. Sulphate of baryta consists of one proportional of sulphuric acid and one of baryta.

40 sulphuric acid
78 baryta
118

641. *Native Sulphate of Baryta*, *Heavy Spar*, or *Baroselenite*, is principally found in the mines of Westmorland and Cumberland, and in Transylvania, Hungary, Saxony, and Hanover. A variety met with in Derbyshire, is called *cawk*. It occurs massive, and crystallized in a great variety of forms. Its primitive figure is a rhomboidal prism, the angles of which are 101° 42′, and 78° 18′. It is harder than carbo-

nate of lime, but not so hard as fluate of lime. Its specific gravity is 4.7.

When native sulphate of baryta is heated it decrepitates and at a high temperature fuses into an opaque white enamel: it was employed in the manufacture of *jasper ware* by the late Mr. Wedgwood. When formed into a thin cake with paste, and heated to redness, it acquires the property of phosphorescence. This was first ascertained by Vincenzo Cascariolo, of Bologna, whence the term *Bologna phosphorus* is applied to it. (186). The artificial sulphate of baryta is used as a pigment, under the name of *permanent white.* It is very useful for marking phials and jars in a laboratory. Sulphate of baryta is sparingly soluble in sulphuric acid.

642. As the native sulphate is a common and abundant compound, several processes have been contrived for obtaining from it pure baryta. This may be effected by reducing the crystallized sulphate to a fine powder, and heating it red hot for half an hour in a silver crucible with three parts of carbonate of potassa: the fused mass is then boiled repeatedly in water, till it no longer affords any thing soluble in that liquid; the insoluble residue, consisting chiefly of carbonate of baryta, may be digested in dilute nitric acid, by which nitrate of baryta is formed, and which will yield the pure earth by exposure to heat as above-mentioned. (635).

Another method consists in exposing to a red heat, in an earthen crucible, a mixture of six parts of finely powdered sulphate of baryta, with one of powdered charcoal, for half an hour. This converts the sulphate into sulphuret of baryta, which is to be dissolved in hot water, the solution filtered and mixed with solution of carbonate of soda as long as it occasions a precipitate, which when washed and dried, is carbonate of baryta. Or, by adding muriatic acid to the liquid sulphuret, sulphur is thrown down and sulphuretted hydrogen evolved, and muriate of baryta formed, which may be filtered off, and if required, decomposed by carbonate of potassa. Or the sulphuret, as it comes out of the crucible, may be thrown into dilute nitric acid, by which sulphuretted hydrogen is evolved, and a nitrate of baryta formed, which may be separated from the remaining impurities by copious washings with hot water.

643. *Phosphuret of Barium* is produced by passing phosphorus over heated baryta; there is an intense action and a phosphuret of a metallic lustre is obtained, which acts upon water, and affords a solution containing *Hypophosphite of Baryta.*—See Chap. IV., Sect. iv.

644. *Hypophosphite of Baryta,* like the other hypophosphites, is very soluble and scarcely crystallizable.

645. *Phosphite of Baryta* was obtained by Berzelius by adding muriate of baryta to phosphite of ammonia; a crust of phosphite of baryta was formed in 24 hours, consisting of

Phosphorous acid	24.31
Baryta	67.24
Water	8.45

Ann. de Chim. et Phys., ii. 231.

646. *Phosphate of Baryta* consists of

28	phosphoric acid
78	baryta
106	

It is insoluble in water; and, therefore, formed by adding a solution of phosphoric acid or phosphate of soda to nitrate or muriate of baryta.

Berzelius has described a crystallizable *Bi-phosphate of Baryta*, obtained by digesting the phosphate in phosphoric acid; and a *Sesquiphosphate*, obtained by pouring the bi-phosphate into alcohol, which occasions a precipitate of a white tasteless powder, composed of 1 proportional of baryta + 1.5 proportional of acid.

647. *Carbonate of Baryta* is found native. Artificially produced, it is a white compound insoluble in water, containing

22	carbonic acid
78	baryta
100	

It is poisonous.

648. *Native Carbonate of Baryta* was first discovered at Anglesark, in Lancashire, by Dr. Withering, and hence acquired the name of *Witherite.* It has also been found in Wales, Cumberland, Durham, Westmorland, and Shropshire. Its primitive crystal is an obtuse rhomboid: sometimes it forms pyramidal six-sided prisms. That found in Lancashire is in globular masses of a radiated structure. It is useful as a source of pure baryta and its salts, and though not soluble in water, is poisonous. It dissolves very sparingly in solution of carbonic acid, whence the superiority of baryta water to lime water in some cases as a test of carbonic acid. The native carbonate of baryta is much more difficult of decomposition by heat than the artificial; if mixed with a little charcoal powder, and kept for some time in a red heat, carbonic oxide escapes, and pure baryta is formed.

649. *Borate of Baryta* is an insoluble white powder.

650. The soluble barytic salts furnish white precipitates of carbonate and sulphate of baryta, upon the addition of carbonate or sulphate of soda. They give a yellow tinge to the flame of spirit of wine. The sulphate is insoluble in nitric acid and in the alcalis, and very sparingly soluble in sulphuric acid.

Nearly all the barytic compounds are poisonous; the safest antidote is solution of sulphate of soda, or dilute sulphuric acid. (ORFILA, *Traité des Poisons*, Tom. i. 2me. p. 167.) The muriate of baryta has been employed in medicine, but the principal use of baryta is in the chemical laboratory. It is possible that pure baryta might be economically used for the decomposition of sulphate of soda, to obtain the pure alcali.

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SECTION VI. *Strontium.*

651. THIS metal is procured from the earth strontia by the same process as barium, which metal it resembles in appearance.

652. *Oxide of Strontium*, or the earth *Strontia*, is procured by the ignition of the pure nitrate; it is of a grey colour and very difficult of fusion when free from water; it forms a *pulverulent*, and a *crystallized hydrate*. Strontia consists of

44 strontium
8 oxygen
—
52

These proportions are theoretically deduced from the sulphate, for 52 parts of strontia combine with 40 parts of sulphuric acid, containing 16 sulphur and 24 oxygen; hence 8, or one third of the oxygen existing in the acid, must be contained in the base (527), and 52 — 8 = 44, the proportion of metal in the protoxide, and the representative number of strontium.

The *pulverulent hydrate* contains

52 strontia
9 water
—
61

At the temperature of 60°, 2 parts of water dissolve 3 of the crystallized hydrate.

1 part of strontia requires about 160 of water at 60° for its solution. *Strontia water* is transparent and colourless; it greens vegetable blues, and its taste is styptic and acrid.

653. *Chlorine and Strontium.*—This compound which has also been called *Muriate of Strontia*, is commonly procured by dissolving carbonate of strontia in muriatic acid. It crystallizes in slender six-sided prisms, soluble in twice their weight of water, at 60°. When chlorine is made to act upon strontia, it is absorbed, and oxygen evolved: the resulting compound contains

44 strontium
36 chlorine
—
80

It is of a grey colour. It dissolves in alcohol, and the solution burns with a purple-coloured flame.

654. *Chlorate of Strontia* is a very soluble and deliquescent salt, difficultly crystallizable, and detonates when thrown upon red-hot coals with a beautiful purple light.

655. *Iodide of Strontium* may be formed as iodide of barium. Dissolved in water, and carefully evaporated, it furnishes delicate prismatic crystals of *Hydriodate of Strontia*, which, heated in close vessels fuses and becomes iodide of strontium by loss of water.

656. *Iodate of Strontia* is a very difficultly soluble compound; it is resolved at a red heat into oxygen, iodine, and strontia.

657. *Nitrate of Strontia* crystallizes in octoëdra and dodecaëdra; it is soluble in its weight of water at 60°. It consists of

52 strontia
54 nitric acid
—
106

Its taste is pungent and cooling. At a red heat the acid is evolved and partly decomposed, and strontia remains.

This salt is used in the *red fire* employed at the theatres, which consists of 40 parts of dry nitrate of strontia, 13 of powdered sulphur, 5 of chlorate of potassa, and 4 of sulphuret of antimony. The chlorate and sulphuret should be separately powdered, and mixed together on paper with the other ingredients; a very small quantity of powdered charcoal may also be added.

658. *Sulphuret of Strontium* may be formed by fusing strontia and sulphur in a green glass tube; or by exposing the powdered sulphate to a red heat with charcoal. It dissolves in water with the same phænomena as sulphuret of potassa, and its solution furnishes, by cautious evaporation, crystals of *hydrosulphuret of strontia.*

659. *Hyposulphite of Strontia* is formed by passing sulphurous acid into the liquid sulphuret: it crystallizes in rhomboids permanent at common temperatures and soluble in about 5 parts of water at 60°. (GAY-LUSSAC, *Annales de Chimie*, lxxxv.) According to Mr. Herschel, this salt is doubly refractive. Its taste is bitter, and it is insoluble in alcohol.

660. *Sulphite of Strontia* has not been examined.

661. *Sulphate of Strontia* occurs native. It is nearly insoluble, 1 part requiring 4000 of water for its solution. When heated with charcoal, its acid is decomposed, and *sulphuret of strontia* is formed, which affords nitrate by the action of nitric acid. This process, equally practicable upon sulphate of baryta (642), is sometimes adopted to obtain the earth. Sulphate of strontia dissolves in hot sulphuric acid, but is thrown down upon adding water. It consists of

52 strontia
40 acid
—
92

662. The *Native Sulphate of Strontia* is sometimes of a blue tint, and has hence been called *celestine*. Sometimes it is colourless and transparent. Its primitive form is a prism of 104° 48′ and 75° 42′ with a rhomboidal basis. It has been found at Strontian in Argyleshire; in the vicinity of Bristol; and at Montmartre near Paris. The finest crystallized specimens are accompanied with native sulphur, from Sicily. Its specific gravity is 3.2.

663. *Hypophosphite of Strontia* has been examined by Dulong: it is a very soluble and difficultly crystallizable salt.

664. *Phosphite of Strontia* has not been examined.

665. *Phosphate of Strontia* is an insoluble white salt, containing

52 strontia
28 acid
—
80

It is soluble in excess of phosphoric acid, which is not the case with phosphate of baryta. It is entirely decomposed by sulphuric acid. By igniting it with charcoal, *phosphuret of strontium* is obtained.

666. *Carbonate of Strontia* exists native. Artificially formed, it is a white insoluble body, containing

52 strontia
22 carbonic acid
—
74

When strongly heated with a little charcoal powder, it is decomposed, carbonic oxide is given off, and pure strontia remains.

667. *Native Carbonate of Strontia* or *Strontianite* is a rare mineral. It has a greenish tint, and occurs in radiated masses, and sometimes in acicular and hexaëdral crystals. It was first discovered in 1787 at Strontian in Argyleshire, whence the name of this earth; it has also been found in Saxony and in Peru. Its specific gravity is 3.6.

This substance was first examined, and the peculiarities of strontia pointed out, by Professor Hope of Edinburgh, in 1791. His experiments are detailed in the *Philosophical Transactions of the Royal Society of Edinburgh*, Vol. iv. p. 44.

668. *Borate of Strontia* was formed by Dr. Hope. It is a white powder soluble in 130 parts of water.

669. There is in many respects a resemblance between strontia and baryta which has led to confusion in analysis.

The following are some of the most striking points of resemblance. They are both found native in the states of sulphate and carbonate only; both sulphates are soluble in excess of sulphuric acid, and nearly insoluble in water; they are decomposable by similar means, as well as the native carbonates: they are both crystallizable from their hot aqueous solutions, and both attract carbonic acid. The carbonates are each soluble with effervescence in most of the acids; but the native carbonates are not so easily acted on as the artificial. Pure ammonia precipitates neither one nor the other.

The following are essential distinctions. Baryta and all its salts, except the sulphate, are poisonous. The corresponding strontitic salts are innocent. Baryta tinges flame yellow; strontia, red. Strontia has less attraction for acids than baryta; hence the strontitic salts are decomposed by baryta. The greater number of the barytic salts are less soluble than those of strontia, and they differ in their respective forms and solubilities. Pure baryta is ten times more soluble in water than pure strontia.

SECTION VII. *Magnesium.*

670. THE metallic base of magnesia has not hitherto been obtained; but, when that earth is negatively electrized with mercury, the resulting compound decomposes water, and gives rise to the formation of *magnesia*. From the properties of the amalgam it appears that it is a white solid metal heavier than water, and highly attractive of oxygen.

671. *Magnesia or Oxide of Magnesium* is concluded, from indirect experiments, to consist of 12 metal + 8 oxygen; its representative

number, therefore, is 20. It may be procured by exposing the carbonate of magnesia to a red heat. Magnesia is a white insipid substance, which slightly greens the blue of violets. Its specific gravity is 2.3; it is almost infusible and insoluble in water. I once succeeded in agglutinating a small portion of this earth in the voltaic flame, and whilst exposed to this high temperature, it was perfectly fused by directing upon it the flame of oxygen and hydrogen. A mixture of magnesia and lime is scarcely more fusible than the pure earth. It does not absorb carbonic acid or moisture, as is the case with the other alcaline earths.

672. *Native Magnesia* is a very rare mineral, and has hitherto been found only at *Hoboken*, in New-Jersey. Its colour is greenish white; its texture lamellar and soft. According to the analysis of Dr. Bruce, it consists of

70	magnesia
30	water
100	

673. *Chloride of Magnesium* may be obtained by passing chlorine over red-hot magnesia; oxygen is expelled, and a substance obtained which moisture converts into muriate of magnesia.

674. *Muriate of Magnesia* is very deliquescent, and difficultly crystallized. Its solution has a bitter saline taste. Exposed to heat and air, muriatic acid flies off, and the magnesia remains pure. It consists of

Magnesia . . .	20
Muriatic acid	37
	57

675. Muriate of Magnesia is found in a few saline springs, and also in the water of the ocean. By evaporating a pint of sea-water we obtain

Common Salt	180.5 grs.
Muriate of Magnesia	23
Sulphate of Magnesia	15.5
Sulphate of Lime	7.1
	226.1

MURRAY'S *Analysis of Sea-Water, Edinburgh Phil. Trans.*, Vol. viii. p. 205.

The average specific gravity of sea-water is 1.026 or 1.028. It freezes at about 28.5°, and does not appear materially to differ in composition in different latitudes, provided it be taken from a sufficient depth. Near the mouths of rivers, and in the vicinities of melting ice or snow, its composition will of course vary.

676. *Chlorate of Magnesia* is a bitter deliquescent salt.

677. *Hydriodate of Magnesia* is deliquescent, and loses hydriodic acid by exposure to heat.

Iodide of Magnesium has not been examined.

678. *Nitrate of Magnesia* crystallizes in rhomboidal prisms, deli-

quescent, and soluble in its weight of water. Its taste is cooling and bitter, and it is decomposed at a red heat. It contains

Magnesia	20
Nitric acid	54
	74

679. *Ammonio-Nitrate of Magnesia* may be obtained by evaporating a mixed solution of nitrate of ammonia and nitrate of magnesia; it forms prismatic crystals of a bitter acrid taste, soluble in about 11 parts of water at 60°, and less deliquescent than their component salts separately.—FOURCROY, *Annales de Chimie*, iv. 215.

680. *Sulphuret of Magnesia.*—Sulphur and magnesia do not appear to form a complete sulphuret, for when melted together the compound does not dissolve in water; and when heated the sulphur burns off.

681. *Hyposulphite of Magnesia* may be formed by boiling flowers of sulphur in solution of sulphite of magnesia; it is bitter very soluble but not deliquescent. Being more soluble in hot than cold water, it readily crystallizes as its solution cools; heated, the sulphur escapes, but it is not very combustible.

682. *Sulphite of Magnesia* is prepared by passing sulphurous acid through water containing diffused magnesia. It forms tetraëdral crystals soluble in 20 parts of water at 60°.

683. *Sulphate of Magnesia* is a commonly occurring compound of this earth, much used in medicine as an aperient. It is largely consumed in the preparation of carbonate of magnesia. It crystallizes in four-sided prisms with reversed dihedral summits; or four-sided pyramids. Its taste is bitter. It is soluble in its own weight of water at 60°. When exposed to a red heat, it loses its water of crystallization, amounting to about 50 *per cent.*, but is not decomposed. It consists of

Magnesia	20
Sulphuric acid	40
	60

In its crystallized state, it may be considered as composed of 1 proportional of dry sulphate + 7 proportionals of water, or 60 sulphate
63 water
———
123

684. This salt is usually obtained from sea-water, the residue of which, after the separation of common salt, is known by the name of *bittern*, and contains sulphate and muriate of magnesia; the latter is decomposed by sulphuric acid: a portion of muriate of magnesia often remains in the sulphate and renders it deliquescent: it is also occasionally obtained from saline springs; and sometimes by the action of sulphuric acid on magnesian limestone. It was once procured from the springs of Epsom in Surrey, and hence called *Epsom salt*. It has been found native, constituting the *bitter salt* and *hair salt* of mineralogists: it not unfrequently occurs as a fine capillary incrustation upon the damp walls of cellars and new buildings.

685. The sulphate of magnesia of commerce is occasionally adul-

terated with small crystals of sulphate of soda; the fraud is detected by the inferior weight of the precipitate, occasioned by adding carbonate of potassa; 100 parts of pure crystallized sulphate of magnesia furnishing a precipitate of about 40 parts of dry carbonate.

686. *Ammonio-Sulphate of Magnesia* may be obtained by mixing solution of sulphate of ammonia with solution of sulphate of magnesia; or by pouring ammonia into a solution of the sulphate of magnesia, in which case, part only of the magnesia is thrown down, the remainder forming with the sulphate of ammonia this triple salt. It crystallizes in octoëdra and consists of

68 sulphate of magnesia
32 sulphate of ammonia
—
100

FOURCROY, *Annales de Chimie*, vi.

687. *Sulphate of Potassa and Magnesia* forms rhomboidal crystals, scarcely more soluble than sulphate of potassa, and of a bitter taste.

688. *Phosphuret of Magnesia*, not examined.

689. *Hypophosphite of Magnesia*, not examined.

690. *Phosphite of Magnesia*, not examined.

691. *Phosphate of Magnesia* is formed by adding the carbonate of magnesia to phosphoric acid. It is insoluble. According to Fourcroy, crystals of phosphate of magnesia may be obtained by mixing the aqueous solutions of phosphate of soda and sulphate of magnesia. The *bi-phosphate* crystallizes in irregular six-sided prisms, soluble in 14 parts of water at 60°, and efflorescent.

692. *Ammonio-Phosphate of Magnesia* is formed by mixing the solutions of phosphate of ammonia, and phosphate of magnesia; it precipitates in the form of a white crystalline powder, or in small four-sided prisms, tasteless, and scarcely soluble in water, but readily soluble in dilute muriatic acid. Exposed to a high temperature it falls into powder, evolves ammonia, and fuses with difficulty. According to Fourcroy, it contains equal weights of phosphate of ammmonia, phosphate of magnesia, and water.

To separate magnesia from other earths, Dr. Wollaston availed himself of the formation of this triple phosphate. A mixture, for instance, of lime and magnesia may be dissolved in muriatic acid; and, upon the addition of bi-carbonate of ammonia, the lime is thrown down in the state of carbonate, but the magnesia is retained by the excess of carbonic acid. Filter and add a saturated solution of phosphate of soda, and in a short time the ammonio-magnesian phosphate falls down, 100 grains of which are equivalent to about 20 of magnesia. In occasionally employing this process, however, I have never been able to throw down the whole of the magnesia, a portion being under all circumstances retained in solution.

693. *Carbonate of Magnesia* is generally procured by adding carbonated alcalis to a solution of sulphate of magnesia. It is a white, insipid, and insoluble powder, which loses its acid at a red heat, and thus affords pure (calcined) magnesia. It contains

20 magnesia
22 carbonic acid
—
12

694. Carbonate of magnesia was first used in medicine early in the last century. It is often obtained from sea-water, after the separation of its common salt. It has been found *native* in Piedmont and Moravia, constituting the mineral called *magnesite*. It has also been found at Hoboken in veins in a serpentine rock, accompanying the native hydrate (672). It is generally white and friable, and in some places in fine acicular crystals.

695. *Bi-carbonate of Magnesia.*—Carbonate of magnesia is soluble in excess of carbonic acid, and this solution affords efflorescent crystals of *bi-carbonate* containing

20	magnesia
44	carbonic acid
64	

This solution of magnesia, in excess of carbonic acid, is very useful in some calculous complaints.

696. *Borate of Magnesia* may be formed artificially. It occurs native in a mineral called *boracite*, hitherto only found in the duchy of Luneburgh. Its primitive form is the cube, but the edges and angles are generally replaced by secondary planes, and four of the angles are always observed to present a greater number of facets than the other four: these crystals become electric by heat; the most complex angles being rendered positive, and the simplest negative. It sometimes contains lime.

697. The salts of magnesia are for the greater part soluble in water. and afford precipitates of magnesia, and of carbonate of magnesia, upon the addition of pure soda, and of carbonate of soda. Phosphate of soda occasions no immediate precipitate when added to a magnesian salt, but the addition of ammonia causes a white precipitate of the tripple ammonio-magnesian phosphate.

698. The fossils which contain magnesia are generally soft and apparently unctuous to the touch; they have seldom either lustre or transparency, and are generally more or less of a green colour. *Steatite* or *soapstone*, *talc*, and *asbestos* may be taken as instances. The *chrysolite* also contains more than half its weight of magnesia. The mineral called *bitter spar*, of which the finest specimens come from the Tyrol, contains 45 *per cent.* carbonate of magnesia, 52 carbonate of lime, and a little iron and manganese. Its primitive crystal is a rhomboid nearly allied to that of carbonate of lime; its angles being 106° 20′, and 73° 80′. It is of a yellowish colour, and a pearly lustre; semi-transparent and brittle. A variety found at *Miemo* in Tuscany, has been called *Miemite*. The species of marble, termed *Dolomite*, found in the Alps, and in Icolmkill in Scotland, contains also a large quantity, generally 40 *per cent.* of carbonate of magnesia. The same may be said of the magnesian limestone of Derby and Nottingham: it is generally of a yellowish colour, and less rapidly soluble in dilute muriatic acid, than the purer limestones, whence the French have termed it *chaux carbonatée lente*. The lime which it affords is much esteemed for cements, but for agricultural purposes it is often mischievous, in consequence of its remaining caustic for a very long time, and thus injuring the young plant.

699. The separation of magnesia and lime is a problem of some importance in analytical chemistry, as they often exist together in the same mineral, more especially in the varieties of magnesian limestone.

When solution of carbonate of ammonia is added to the mixed solution of lime and magnesia in nitric or muriatic acids, carbonate of lime falls, and the magnesia is retained in solution and may be separated by boiling: this method, however simple, is not susceptible of great accuracy, for a portion of carbonate of lime will always be retained along with the magnesia in solution, and a triple ammoniaco-magnesian salt is also formed. Mr. R. Phillips (*Quarterly Journal*, vi. 317) proposes the following process: "To the muriatic or nitric solution of lime and magnesia, add sulphate of ammonia in sufficient quantity; evaporate the mixture gradually to dryness, and then heat it to redness till it ceases to lose weight by the volatilization of the muriate or nitrate of ammonia formed: note the weight of the mixed salt, reduce it to powder and wash it with a saturated solution of sulphate of lime till all the sulphate of magnesia appears to be dissolved; dry the sulphate of lime left, and by deducting its weight from that of the mixed sulphates the quantity of sulphate of magnesia dissolved will appear." After repeated trials of the various modes of separating lime and magnesia, I am induced to consider the following as least defective. To the mixed solution of lime and magnesia add oxalate of ammonia slightly acid, collect the precipitate, wash and dry it. 65 parts indicate 28 of lime. If nitric or muriatic acid were used for solution, the magnesia may afterwards be obtained by evaporation and heating the residue to redness in a platinum crucible till it ceases to lose weight. If sulphuric acid were the solvent, the same operation affords dry sulphate of magnesia of which 60 parts are equivalent to 20 magnesia.

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Section VIII. *Manganese.*

700. The common ore of manganese is the black or peroxide, which is found native in great abundance.

The metal may be procured by exposing the protoxide mixed with charcoal, to an intense heat. It is of a bluish white colour, very brittle, and difficult of fusion. When exposed to air, it becomes an oxide. Its specific gravity is 8.

701. *Manganese and Oxygen.*—There are three definite oxides of manganese. The *protoxide* may be obtained by digesting the native black oxide in muriatic acid. Chlorine is abundantly evolved, and the hydrogen of the muriatic acid unites with part of the oxygen of the oxide to produce water. The metal thus partly deoxidized, is dissolved by the remaining muriatic acid, forming a *muriate of manganese*. Iron is almost always present, which, as Mr. Hatchett has shown, may be easily separated by neutralizing the muriatic solution with ammonia. The oxide of iron is directly precipitated, but oxide of manganese remains in solution and may be separated by *excess* of ammonia*. The solutions of protoxide of manganese furnish a white

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* On the separation of iron from manganese, see *Quarterly Journal of Science and the Arts*, Vol. vi. p. 153.

precipitate with the alcalis, which is a *hydrated oxide of manganese*, and which, when dried in close vessels, acquires an olive colour, and is the *protoxide*. Exposed to moist air, it passes into the state of deutoxide and peroxide.

702. When peroxide of manganese is heated red-hot till it ceases to give out gas, a dark reddish-brown *deutoxide* of manganese remains, which, when acted upon by sulphuric acid, is, according to Gay-Lussac, resolved into protoxide and peroxide. Exposed to moist air it absorbs oxygen, and is partly re-converted into peroxide. The deutoxide is most easily obtained pure, by triturating peroxide of manganese in fine powder with superoxalate of potassa and water: a pink solution is obtained, from which ammonia throws down the deutoxide.

703. The *Peroxide of Manganese* is black; it is not soluble in acids; and abounds as a natural product.

Native Peroxide of Manganese is found in Devonshire, Somersetshire, and Aberdeenshire, and occurs compact, and crystallized. The crystallized varieties have a grey metallic lustre, and are found acicularly radiated, and in rhomboidal prisms. It is generally blended with sulphate of baryta.

704. It appears probable that these are the only definite oxides of manganese. Their composition is variously stated by various chemists; according to the analysis of Berzelius (*Annales de Chimie*, lxxxvii.) they are composed as follows:

	Protoxide.	Deutoxide.	Peroxide.
Manganese	*100.*	*100.*	*100.*
Oxygen	*28.1*	*42.16*	*56.2*

From which it appears that the proportions of oxygen to each other, are as 1., 1.5, and 2; and 28.1 : 100 : : 8 : 28.4, as the representative number of manganese. Dr. Davy's analysis of the chloride of manganese (707) which was made in an unexceptionable way, gives the number 28.6. As further experimental evidence is wanting, we shall not be far from the truth in assuming [*]28.0 as the equivalent of manganese, and the three oxides will then consist of

	Protoxide.		Deutoxide.		Peroxide.
Manganese, 1 proport.	28.0		28.0		28.0
Oxygen . . . 1	8	1.5 propl.	12.	2 propl.	16.
	36		40		44

705. When equal parts of black oxide of manganese and nitre are ignited, a compound results which has been called *cameleon mineral*, in consequence of the changes of colour which its aqueous solution exhibits. M. M. Chevillot and Edwards have ascertained, that in this compound the black oxide of manganese has absorbed an additional proportion of oxygen and acquired the property of forming a neutral *manganesate of potassa*, which exists in the red cameleon, and may be obtained in crystals. When there is excess of alcali, the cameleon is green.—*Annales de Chimie et Physique*, Tom. iv.

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[*] Thomson in his late paper (Ann. Phil. vol. 17, for April 1821), finds by experiment the composition of sulphate of manganese

Sulphuric acid . . . . 5. } which when the atom of { 40
Protox. mang. . . . . 4.5 } hydrogen = 1 gives { 36; now

deducting 1 atom oxygen=8, leaves 28 for manganese, which will be adopted here.

706. *Manganese and Chlorine.*—By burning the metal in chlorine, or by exposing muriate of manganese to a strong heat, a pink semitransparent flaky substance is obtained, which, when dissolved in water, produces a muriate of manganese.

707. *Muriate of Manganese* may also easily be formed by heating excess of the black oxide with muriate of ammonia in a crucible, dissolving the mass in water and filtering. If this solution be evaporated to dryness and fused out of the contact of air, the crystallized chloride is obtained. Heated in contact of air, it is decomposed, and oxide of manganese remains. In this decomposition it is a question whether the chlorine is expelled by the superior attraction of the oxygen for manganese; or whether the moisture in the air, or in the compound itself is concerned in the change. This chloride consists, according to Dr. Davy (*Phil. Trans.* 1812, p. 184) of

54 chlorine
46 manganese
——
100*

So that it may be regarded as a compound of

1 proportional manganese 28
1 ——— chlorine 36
—
64

708. *Chlorate of Manganese* has not been examined, nor has the action of iodine or of its acids upon this metal been investigated.

709. *Nitrate of Manganese.*—Dilute nitric acid readily dissolves protoxide of manganese, and forms a very soluble and difficultly crystallizable *proto-nitrate.* The same salt may be obtained by digesting peroxide of manganese in nitric acid with a portion of gum or sugar, which abstracts oxygen, carbonic acid is evolved, and the protoxide dissolved by the acid. Exposed to light, the solution of the protonitrate lets fall a portion of peroxide of manganese.

When dilute nitric acid is poured upon the deutoxide of manganese, a protonitrate and peroxide are formed.

The composition (theoretical) of nitrate of manganese is

36 protoxide
54 acid
—
90

710. *Manganese and Sulphur* appear unsusceptible of combination; but a compound of oxide of manganese and sulphur is found in Transylvania and Cornwall. It is of a blackish grey colour and metallic lustre. The black oxide of manganese heated with sulphur forms a greenish compound, and abundance of sulphurous acid is evolved: is this a sulphuret, or a sulphuretted oxide of manganese?

711. *Hyposulphite of Manganese* remains in solution when sulphate of manganese is decomposed by hyposulphate of lime.

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* This analysis of Dr. John Davy, differs from all the compositions of manganese, and may be considered as incorrect. Thomson, by the experiment last alluded to, has proved it composition to be

Chlorine	4.5	36.
Manganese	3.5	28.

712. *Sulphate of Manganese* is formed by dissolving the protoxide or protocarbonate in the acid, and evaporating to dryness: a white *protosulphate* is formed, which crystallizes in rhomboidal prisms, and consists of

36 protoxide
40 sulphuric acid
76

It is very soluble in water, and has a bitter styptic taste: at a bright red heat it gives out oxygen, and sulphurous acid and deutoxide of manganese remain. It may also be obtained by mixing peroxide of manganese into a paste with sulphuric acid, and heating it in a basin nearly to redness: oxygen is evolved, and the dry mass washed with water affords the sulphate.

713. *Deutosulphate of Manganese* is formed by digesting the deutoxide in sulphuric acid diluted with its bulk of water: a red solution is formed, but the salt cannot be obtained in a neutral or separate state, for the application of heat evolves oxygen, and forms protosulphate. It is, probably, to a little deutosulphate that the occasional red tinge of the protosulphate is to be attributed.

714. *Phosphuret of Manganese* is of a blue white metallic lustre, and considerably inflammable.

715. *Phosphite* and *Hypophosphite of Manganese* have not been examined.

716. *Phosphate of Manganese* is precipitated in the form of a white insoluble powder, by adding phosphate of soda to muriate of manganese.

717. *Carbonate of Manganese* is white, insipid, and insoluble in water. It is precipitated by alcaline carbonates from the protomuriate or protosulphate, and consists of

36 protoxide
22 carbonic acid
58

718. The salts of manganese containing the protoxide are mostly soluble in water, and the solution becomes turbid and brown by exposure to air. They are not precipitated by hydriodic acid; they furnish white precipitates with the alcalis, which soon become discoloured by exposure to air; they are precipitated white by ferro-prussiate of potassa, and yellow by hydrosulphuret of ammonia.

719. The native peroxide of manganese is used in the laboratory as a source of oxygen, and is largely employed in the preparation of chlorine, especially by the bleachers. It is used in glass-making, and, when added in excess, gives it a red or violet colour. It is also employed in porcelain painting; and it gives common earthen-ware a black colour, by being mixed with the materials before they are formed into vessels.

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SECTION IX. *Iron.*

720. THE most important native combinations of iron, whence the immense supplies for the arts of life are drawn, are the oxides. Iron is also found combined with sulphur, and with several acids; it is so abundant that there are few fossils free from it. It is also found in some animal and vegetable bodies; and in several mineral waters.

Iron is a metal of a blue white colour, fusible at a white heat. Its specific gravity is 7.77. It has not been so long known as many of the other metals; it was, however, employed in the time of Moses for cutting instruments. It is extremely ductile, but cannot be hammered out into very thin leaves.

721. Iron is sometimes found native, and is usually regarded as of meteoric origin, for it is invariably alloyed by a portion of the metal nickel, and a similar alloy is found in *meteoric stones*. *Native Iron* is flexible, cellular, and often contains a green substance of a vitreous appearance. It has been found in Africa, in America, and in Siberia, where a mass of it weighing 1600 lbs. was discovered by Professor Pallas. The mass found in Peru, described by Don Rubin de Celis, weighed 15 tons. In the year 1751, a mass of the same substance was seen to fall from the atmosphere in Croatia. It appeared as a large globe of fire, and is preserved in the imperial museum of Vienna.

722. *Iron and Oxygen.*—Exposed to heat and air, iron quickly oxidizes. It unites with oxygen in at least two proportions. The *protoxide* may be procured by precipitating a solution of sulphate of iron by potassa, washing the precipitate out of the contact of air, and drying it at a red heat. It is black, and consists of 28 iron + 8 oxygen = 36. It is supposed by M. Gay-Lussac, that in drying, an additional proportion of oxygen is always absorbed, and that the black oxide is a deutoxide composed of 100 metal + 37.8 oxygen; (*Ann. de Chim. et Phys.*, Tom. i.) but there is some reason to doubt the accuracy of this conclusion.

The recently precipitated protoxide of iron is sparingly soluble in ammonia, and in carbonated alcalis.

Black protoxide of iron may also be obtained by burning iron in oxygen gas: this very beautiful experiment was devised by Dr. Ingenhous, and is best performed by attaching a straight piece of watch spring, wound round with harpsichord wire, to the stopper of an air-jar of oxygen gas: the end of a brimstone match may be attached to the wire, and inflamed at the time of plunging it into the gas; it heats the wire red hot, which then burns and drops in black globules of oxide into the water beneath.

This oxide of iron used to be prepared for pharmaceutical use, by moistening iron filings with a small quantity of water, and exposing them to the air for a day or two; a quantity of black oxide thus forms, which is separated by washing, and the process repeated till the whole of the metal is thus oxidized. It was called *martial ethiops*. It is black, tasteless, and insoluble in water.

723. When protoxide of iron is boiled in nitric acid, and precipitated by ammonia, washed, and dried at a low red heat, it increases in weight and acquires a brown colour. This is the *peroxide*, composed of 28 iron + 12 oxygen = 40. It has sometimes been called *Saffron of Mars*.

724. The number 26, as the equivalent of iron is founded on the presumption that it exists as a protoxide in the sulphate: now 100 grains of pure iron, during solution in sulphuric acid, evolve 170 cubic inches of hydrogen at mean temperature and pressure, and consequently 85 cubic inches of oxygen = 28.68 grs. have been transferred to the iron: and 28.68 : 100 : : 8 : 27.9. The quantity of oxygen in the peroxide of iron is shown to be to that in the protoxide as 3 to 2 by the following experiment. 100 grains of iron were dissolved in nitric acid and the solution evaporated to dryness, and the residue sufficiently

heated to drive off the whole of the acid: 143 grains of peroxide remained. So that the composition of these oxides stands thus:

	Protoxide.	Peroxide.
Iron	100	100
Oxygen	28.68	43
	128.68	143

And 28.68 . 43 : : 8 : 12 = $\frac{1}{2}$ proportional of oxygen.

M. GAY-LUSSAC (*Ann. de Chim. et Phys.* i., and *Ann. de Chim.* lxxx.) has detailed some experiments, which he considers as demonstrating the existence of a third definite oxide of iron, intermediate between the above oxides, and composed of iron 100 + oxygen 37.8. Such a compound he thinks is obtained by passing steam for a length of time over red-hot iron: it seems, however, very questionable whether this be a definite compound: it is rejected by Berzelius, who only admits the oxides above described.

M. Thenard, in describing the oxides of iron, (*Traité* ii. 75. *Edit.* 2.) considers the octoëdral and magnetic iron ores as composed of this deutoxide, and does not allow of the existence of native protoxide of iron. In the present state of the question, however, I should feel rather inclined to view this deutoxide as a mixture of the protoxide and peroxide, than as any definite compound, more especially as the analyses of the native magnetic oxides give variable proportions of oxygen.

In order that the representative number of iron may also be its equivalent number, it is represented by 28. But the peroxide, instead of consisting of 1 proportional metal + 2 oxygen, consists of 1 proportional metal + 1.5 oxygen; and the chloride and perchloride bear the same relation to each other. The case however is different with the sulphurets; for the sulphuret consists of 1 proportional iron + 1 sulphur: and the bi-sulphuret of 1 iron + 2 sulphur.

M. Gay-Lussac has shown the curious fact, that although red-hot iron decomposes water, hydrogen is capable of decomposing all the oxides of iron at a red heat.—*Ann. de Chim. et Phys.*, i. 37.

725. The *Native Oxides of Iron* constitute a very extensive and important class of metallic ores. They vary in colour, depending upon mere texture in some cases; in others, upon the degree of oxydizement. Some varieties are magnetic, and those which contain least oxygen are attracted by the magnet.

Magnetic Iron Ore is generally black, with a slight metallic lustre. It occurs massive and octoëdral. It is often sufficiently magnetic to take up a needle. Its specific gravity is 4.5. It occurs chiefly in primitive countries, and is very abundant at Roslagen in Sweden, where it is manufactured into a bar-iron particularly esteemed for making steel.

Another variety of oxide of iron is called *iron glance*, and *micaceous iron ore*. It is found crystallized of singular beauty, in the isle of Elba; and occasionally among the volcanic products of Vesuvius and the Lipari Islands.

A third variety is *Hæmatite*, or red iron-stone; it occurs in globular and stalactitic masses, having a fibrous and diverging structure. In this country it abounds near Ulverstone in Lancashire; and most of our iron-plate, and wire, is made from it. Sometimes it is of a brown, black, or ochraceous colour.

A fourth variety of oxide of iron, is known under the term of *clay-iron-stone*, on account of the quantity of argillaceous earth with which it is contaminated. It is found in masses of different shapes and sizes, and sometimes in small rounded nodules like peas. Some of the globular masses are called *ætites*. It is abundant in the coal formations of Shropshire, South Wales, Staffordshire and Scotland.

Though this is far from the purest iron ore found in this country, it is the chief source of the cast and bar iron, in ordinary use. Its employment is chiefly referable to the coal which accompanies it.

The essential part of the process by which these ores of iron are reduced, consists in decomposing them by the action of charcoal at high temperatures. The argillaceous iron of Wales, Shropshire, *&c.*, is first roasted, and then smelted with lime-stone and coke: the use of the former being to produce a fusible compound with the clay of the ore, by which the latter is enabled to act upon the oxide, and to reduce it to the metallic state.

726. The two oxides of iron form distinct salts with the acids.

The salts containing the black oxide are of a green colour, mostly crystallizable, become reddish brown by exposure to air, and their solutions absorb nitric oxide gas and become of a deep olive colour.

The salts with the brown oxide do not, with very few exceptions, crystallize: they are brown, soluble in alcohol, and do not absorb nitric oxide.

The alcalis precipitate hydrated oxides from these solutions.

727. *Iron and Chlorine* unite in two proportions; the *chloride* may be obtained by evaporating *protomuriate of iron* to dryness, and exposing the residuum to a red heat, out of the contact of air. A grey brittle lamellar substance is formed, consisting of one proportional of iron and one of chlorine; 28 + 36.

That the chlorine in the protochloride of iron is to that in the perchloride as 1 to 1.5, is shown by Dr. Davy in his valuable paper on the chlorides, (*Phil. Trans.*, 1812, 169.) and the equivalent number of iron, as deduced from his analysis, is somewhat above that here adopted. It must be confessed that the anomaly in the oxides and chlorides of iron throws some difficulty in the way of applying to them their equivalent numbers, but as the foundations of chemistry are purely experimental, we must not endeavour to do away that difficulty by a theoretical substitute. There is a difference in the relations of iron to oxygen and chlorine, compared with its relation to sulphur, which does not exist elsewhere; of the cause of this difference we are at present ignorant.

728. When iron wire is heated in chlorine, it burns with a red light, and produces a compound which rises in beautiful brown scales. It is the *perchloride of iron*, and consists of one proportional of iron, and one and a half of chlorine; 28+54. The chloride and perchloride of iron produce *protomuriate* and *permuriate* of iron when acted upon by water.

729. *Chlorate of Iron* has not been examined.

730. *Muriate of Iron.*—When iron filings are dissolved in muriatic acid, a greenish brown solution results, which contains a mixture of the protomuriate and permuriate.

731. *Protomuriate of Iron* is best obtained by digesting black sulphuret of iron in dilute muriatic acid; sulphuretted hydrogen is evolved, and a green solution obtained, which, filtered and evaporated, yields pale green crystals, very soluble, and of a styptic taste. This salt abundantly absorbs nitric oxide gas; the solution is of a very deep brown colour; when heated, red oxide of iron falls and a portion of ammonia is formed; a great part of the gas at the same time escapes.

This salt may also be obtained by dissolving iron filings in muriatic acid excluded from air; but the above process is preferable, as the sulphuretted hydrogen prevents any part of the iron passing into the state of permuriate.

732. *Permuriate of Iron* is formed by digesting the peroxide in muriatic acid: it dissolves without the evolution of chlorine, and when evaporated to dryness, furnishes a reddish brown deliquescent mass of a very astringent taste, soluble both in water and alcohol. It forms the basis of the *tinctura ferri muriatis* of the London *Pharmacopœia*. Permuriate of iron is also formed by exposing the protomuriate to air; and by acting upon it by nitric acid. Exposed to heat, muriatic acid, chlorine, and water are evolved, chloride of iron sublimes, and a portion of peroxide remains in the retort.

733. When muriate of ammonia and peroxide of iron are mixed and exposed to heat in a proper subliming vessel, a yellow sublimate is obtained, which is the *ens veneris* and *flores martiales* of old pharmacy: the *ferrum ammoniatum* of the present *Pharmaeopœia;* it consists chiefly of muriate of ammonia, with a small but variable proportion of permuriate of iron.

734. *Iodine and Iron* readily form a brown compound, fusible at a red heat, and which, when acted upon by water, forms a *hydriodate* of a green colour.

735. *Iodate of Iron* has not been examined.

736. The *nitric acid* dissolves the protoxide and peroxide of iron, and produces a green *protonitrate* and a red *pernitrate*.

Nitric acid, diluted with a very little water, acts violently on iron and peroxidizes it, a vast quantity of gas being at the same time generated, which consists of a mixture of nitrous and nitric oxides; and a solution is formed of a reddish brown colour containing *pernitrate* of iron, and affording a brown precipitate to the alcalis.

If the nitric acid be considerably diluted, (sp. gr. 1.16) the action is slow and very little gas escapes; the solution acquires an olive brown colour from the nitric oxide which it contains, but exposed to the air it becomes pale green in consequence of the escape of that gas. The alcalis produce a green precipitate in this solution: it cannot be obtained in crystals by the usual process, and passes into pernitrate by exposure to air.

737. *Sulphur and Iron.*—There are two sulphurets of iron: the *black sulphuret* is composed of 28 iron + 16 sulphur; and the *yellow sulphuret*, or *bi-sulphuret*, of 28 iron + 32 sulphur. The former compound is produced by melting sulphur with iron filings; it exists in nature under the name of *magnetic pyrites:* the bi-sulphuret is exclusively a natural product, very abundant, and called *iron pyrites*.

Magnetic pyrites is not found crystallized; it is generally brown, or whitish yellow, and is not a common mineral.

Common pyrites is found massive, and crystallized in a variety of forms; its primitive form is the cube. It often occurs in nodules. Its colour is different shades of brass yellow.

That the magnetic pyrites contains just half the proportion of sulphur existing in the common pyrites was first shown by Mr. Hatchett. (*Phil. Trans.*, 1804.)

The principal use of pyrites is in the formation of *green vitriol*, for which purpose the ore is gently roasted and exposed to air and moisture. Some varieties are spontaneously decomposed, and furnish this salt. Pyrites has also lately been used in the production of sulphuric acid (325.)

738. *Sulphates of Iron.*—The sulphuric acid with the protoxide of iron forms a *protosulphate of iron*, which crystallizes in green rhomboidal prisms, of a styptic taste, soluble in twice their weight of cold water, and insoluble in alcohol. This salt is called *copperas* or *green vitriol*, and is often prepared by exposing roasted pyrites to moisture, in which case it is impure. It is usually formed by dissolving iron filings, or turnings, in dilute sulphuric acid, filtering and evaporating the solution, and setting it aside to crystallize. It is also obtained, perfectly free from persulphate, by acting upon sulphuret of iron by dilute sulphuric acid. It consists of one proportional of protoxide = 36 + 1 proportional of acid = 40, and in its crystallized state contains seven proportionals of water = 63. Its solution absorbs nitric oxide gas, and acquires a deep brown colour; it also absorbs chlorine, muriatic acid is formed, and the iron becomes peroxidized, so that water is here decomposed.

Exposed to air and moisture, the protosulphate of iron gradually absorbs oxygen, and is partly converted into a persulphate. It may also be converted into persulphate by nitric acid. When heated, it fuses in its water of crystallization, and at a high temperature evolves a mixture of sulphurous and sulphuric acids, peroxide of Iron remaining in the vessel: by this process sulphuric acid used formerly to be prepared, and the residue was known under the name of *caput mortuum vitrioli* or *colcothar*. If the green crystals of this salt be exposed to a temperature of about 300°, they lose a portion of water, and crumble down into a white powder.

739. *Native Green Vitriol* is frequently found associated with iron pyrites, being produced by its decomposition: it occurs in several of our coal mines.

740. *Persulphate of Iron* is obtained by dissolving the moist red oxide in dilute sulphuric acid; it does not crystallize, but affords, by evaporation, a brown deliquescent mass, consisting of 1 proportional of peroxide + 1.5 sulphuric acid, or 40 oxide + 60 sulphuric acid. It is formed in the mother waters of the sulphate. Its taste is highly astringent, and when dry it becomes white: if in this state it be digested in hot sulphuric acid, or if peroxide of iron, recently precipitated from the pernitrate, be boiled with excess of sulphuric acid, the solution yields octoëdral crystals nearly white, and of a sweetish styptic taste: these are probably a *bi-persulphate of iron*.

741. *Phosphuret of Iron* may be formed by dropping phosphorus into a crucible containing red-hot iron wire; it is a brittle grey compound, and acts upon the magnet. Upon the subject of the magnetic qualities of the sulphuret and phosphuret of iron, the reader is referred to Mr. Hatchett's analysis of the magnetical pyrites. (*Phil. Trans.*, 1804).

742. *Phosphates of Iron.*—These are both insoluble, and may be formed by adding solution of phosphate of soda, to protosulphate and persulphate of iron. The *protophosphate* of iron is of a pale blue colour; the *perphospate* is white.

743. *Native Protophosphate of Iron* occurs in the form of a blue earthy powder, and also in prismatic crystals. The former has sometimes improperly been termed *Native Prussian Blue*, and has been found in alluvial soil: the latter occurs with iron pyrites in Cornwall.

744. *Iron and Carbon.*—The different kinds of cast iron and of steel contain more or less carbon, which materially affects their properties. The substance termed *Plumbago*, *Graphite*, or *Black Lead*, is generally

regarded as a true *carburet of iron:* this is not an uncommon mineral, though rarely found of sufficient purity for the manufacture of pencils: at Borrodale in Cumberland, where it occurs particularly pure, it is in imbedded masses in slate and grauwacke: the coarser kinds and the dust, are melted with sulphur for common carpenters' pencils: crucibles are sometimes made of it, and it forms an ingredient in compositions for covering cast-iron, and for diminishing friction in machines. According to Messrs. Allen and Pepys it consists of

95	carbon
5	iron
100	

It may here be observed, that considerable difficulty attends the accurate analysis of compounds of carbon and iron, in estimating the proportion of the former; this has generally been indirectly effected by ascertaining the quantity of iron, and considering the loss of weight as carbon, a method obviously objectionable. If the action of dilute sulphuric acid be resorted to, a portion of carbon is carried off by hydrogen; the same is the case with muriatic acid; and if nitric acid be used, some carbonic acid may be formed, and artificial tannin is produced.

Plumbago is infusible, and burns with great difficulty: its composition was ascertained by the above-mentioned chemists, by exposing it in the apparatus used for burning the diamond, to a current of oxygen at a red heat, and ascertaining the quantity of carbonic acid and of oxide of iron thus produced.

745. *Carbonic Acid* may be combined with the protoxide of iron, by adding carbonate of potassa to sulphate of iron; a green precipitate of *protocarbonate of iron* falls, which, exposed to air, becomes brown, and evolves carbonic acid. Solution of bi-carbonate of potassa occasions a white precipitate with sulphate of iron, part of which is re-dissolved on adding excess of the carbonated alcali.

746. *Spathose Iron Ore* is a native carbonate of iron, containing a little manganese and carbonate of lime. It occurs in Germany, and in some parts of Cornwall, crystallized in imperfect rhomboids. Its colour is yellowish, or brownish, grey.

747. When hydrocyanate of potassa is added to the solutions of salts of iron, it occasions a bluish white precipitate in those containing the protoxide, and a blue precipitate in those containing the peroxide. The former precipitate is probably a ferrocyanate of iron, containing the protoxide; the latter, a ferrocyanate containing the peroxide, and which has been long known under the name of *Prussian Blue.*

748. Prussian blue is usually prepared by the following process:—Equal parts of subcarbonate of potassa and some animal substance, such as dried blood, or horn shavings, are heated red hot, in a crucible, and six or eight parts of water are poured upon the mixture when it has quite cooled. The solution is filtered and found to contain *hydrocyanate of potassa*, along with carbonate of potassa, and some other products. It is mixed with a solution containing two parts of alum and one of sulphate of iron; a precipitate falls, at first of a dingy green hue, but which, by copious washings with very dilute muriatic acid, acquires a fine blue tint, and is called *Prussian Blue*, having been discovered by Diesbach a colour-maker of Berlin, in 1710. The first description of the mode of preparing it is given by Woodward in the *Phil. Trans.* for 1724.

In this process the animal matter is decomposed, and resolved into a variety of products arising from the reunion of its ultimate component parts. The matter remaining in the crucible contains cyanuret of potassium, and when acted upon by water, hydrocyanate of potassa, with a little carbonic acid and ammonia, is formed in consequence of the decomposition of a portion of the water; and consequently the principal salts contained in the washings of the black matter remaining in the crucible are carbonate and hydrocyanate of potassa, which, when added to a solution of sulphate of iron, form a precipitate of oxide and ferrocyanate of iron; the former is removed by the dilute muriatic acid. The aluminous earth of the alum gives a *body* to the precipitate, which improves it as a pigment.

The above seems to be the simplest view of the formation and composition of Prussian blue; a variety of other opinions respecting its nature have been entertained, but they require further experimental verification.

749. Pure Prussian blue, obtained by adding ferrocyanate of potassa to solution of persulphate of iron, is a tasteless substance insoluble in water and alcohol. It is not acted upon by dilute nitric, sulphuric or muriatic acids, which renders it extremely improbable that it should be a hydrocyanate of iron, and strengthens the opinion of Mr. Porrett, that it is a *ferrocyanate*, or a compound of peroxide of iron with the peculiar acid mentioned below (752), and containing hydrogen, oxygen, iron, and cyanogen.

750. When Prussian blue is boiled with potassa it is decomposed; it loses its blue colour, oxide of iron is separated, and on filtering and evaporating the solution, a triple salt is obtained, consisting of hydrocyanic acid, potassa, and oxide of iron; this has been called *triple prussiate of potassa*, and *ferrocyanate of potassa*. It is best formed by adding powdered Prussian blue, previously heated with a dilute sulphuric acid composed of one part of acid and five of water, and afterwards washed, to a hot solution of potassa, as long as its colour is destroyed. This salt forms permanent yellow cubic and tabular crystals, more soluble in hot than cold water, insoluble in alcohol, and of a peculiar taste. Boiled with dilute sulphuric or muriatic acids, hydrocyanic acid is given out, and a precipitate formed similar to that which the salt produces in a solution of proto-sulphate of iron. It is decomposed in a retort at a red heat, hydrocyanic acid and ammonia are evolved, and the residue consists of charcoal, potassa, and iron.

Exposed to a red heat in a platinum crucible, a brown mass is obtained, which, washed with water, deposits a grey cyanuret of platinum. The aqueous solution furnishes, on evaporation, hydrocyanate of potassa and a large quantity of transparent colourless prismatic crystals.—THENARD, *Traité*, 2d edit., iii. 528.

751. The *ferrocyanates of ammonia*, *soda*, *lime*, *magnesia*, *baryta*, and *strontia*, may be obtained by boiling those alcalis and earths with Prussian blue.

752. Mr. Porrett (*Phil. Trans.*, 1814.) considers the ferrocyanates as compounds of the respective bases, with an acid consisting of the elements of the hydrocyanic acid united to the protoxide of iron. This acid he terms *ferrochyazic acid*, derived from the initial letters of carbon, hydrogen, and azote. He obtained this acid dissolved in water, by adding to a solution of ferrocyanate of baryta just sulphuric acid enough to precipitate the baryta. It has a pale yellow colour, no smell, and is decomposed by a gentle heat or strong light, in which case hydrocyanic acid is formed, and white hydrocyanate of iron is

deposited, which becomes blue by exposure. Gay-Lussac, observing the production of the ferrocyanate of potassa by adding protoxide of iron to hydrocyanate of potassa, supposes that a portion of the hydrocyanic acid is decomposed by the oxide, giving rise to a compound of cyanuret of iron with hydrocyanate of potassa.

753. The following table shows the colours of the precipitates occasioned by solution of ferrocyanate of potassa, in different metallic solutions :

METAL.	SOLUTION.	PRECIPITATE.
MANGANESE	Neutral protomuriate	White
IRON	Neutral protosulphate	White or pale blue
Ditto	Permuriate	Prussian blue
ZINC	Muriate	Yellowish white
TIN	Acid protomuriate	White, then yellow and bluish
Ditto	Acid permuriate	Pale yellow
CADMIUM . . .	Muriate	
COPPER	Protomuriate	Lilac
Ditto	Pernitrate	Deep brown
LEAD	Nitrate	White
ANTIMONY . .	Tartrate of antimony and potassa	0
BISMUTH . . .	Tartrate of bismuth and potassa	0
COBALT	Muriate	Pale green
URANIUM . . .	Sulphate	Deep brown
TITANIUM . .	Acid muriate	Deep blue (from acid
Ditto	Neutral sulphate	Sap Green
CERIUM		
TELLURIUM .		
ARSENIC . . .	White oxide	
Ditto	Arsenic acid	
NICKEL	Sulphate	Grey
MERCURY . .	Acid nitrate	Greenish white
Ditto	Acid pernitrate	Ditto
Ditto	Corrosive sublimate	White
RHODIUM . . .		
PALLADIUM .		
SILVER	Nitrate	Cream colour
GOLD	Muriate	0
PLATINUM . .	Nitrate	Yellow

All the above precipitates appear to be ferrocyanates, for when treated with solution of potassa, a ferrocyanate of potassa is obtained.

754. *Borate of Iron* is of a yellow colour and insoluble. It is formed by adding borate of soda to sulphate of iron.

755. The salts of iron are mostly soluble in water, and the solution is reddish brown, or becomes so by exposure to air. It affords a blue precipitate with ferro-cyanate of potassa; and a black precipitate with hydrosulphuret of ammonia. Infusion of gall-nuts produces a black or deep purple precipitate. The hydriodic acid occasions no change.

756. Of the alloys of iron, *tin-plate* is the only one of consequence. It is made by dipping clean iron plates into melted tin. The process is described at length by Mr. Parkes. (*Quarterly Journal*, Vol. viii. 141.) When tin-plate is washed over with a weak acid, the crystalline texture of the tin becomes beautifully evident, forming an appearance which has been called *moiré metallique.*—*Quarterly Journal of Science*, Vol. v. p. 368.

757. An extremely important part of the chemical history of iron relates to the varieties of the metal which are found in commerce. These are much too numerous to be dwelt upon here; so that we shall limit our observations to the principal of them only, which are *cast iron, wrought iron*, and *steel.*

Of cast iron there are two principal varieties distinguished by the terms *white* and *grey*. The first is very hard and brittle, and, when broken, of a radiated texture. Acids act upon it but slowly, and exhibit a texture composed of a congeries of plates, aggregated in various positions.—Daniell, *Quarterly Journal of Science and Arts*, Vol. ii. p. 280.

Grey or mottled iron is softer and less brittle; it may be bored, and turned in the lathe. When immersed in dilute muriatic acid, it affords a large quantity of black insoluble matter, which Mr. Daniell considers as a triple compound of carbon, iron, and silicium, and which has some very singular properties. The texture of the metal resembles bundles of minute needles.

Cast iron is in this country converted into wrought iron by a curious process, called *puddling*. The cast iron is put into a reverberatory furnace, and when in fusion is stirred, so that every part may be exposed to the air and flame. After a time the mass heaves, emits a blue flame, and gradually grows tough and becomes less fusible, and at length congeals. In that state it is passed successively between rollers, by which a large quantity of extraneous matter is squeezed out, and the bars are now malleable. They are cut into pieces, placed in parcels in a very hot reverberatory, and again hammered or rolled out into bars. They are thus rendered more tough, flexible, and malleable, but much less fusible, and may be considered as nearly pure iron.

Analysis shows that cast iron contains oxygen, carbon, often sulphur and phosphorus, either silica or silicium, and it appears very probable that calcium exists in some of the varieties.

By the processes of puddling and rolling, these substances are burned away or squeezed out, and thus malleability is conferred upon the metal by rendering it more pure. A specimen of cast iron analyzed by Berzelius afforded Iron 91.53—Manganese 4.57—Carbon 3.90.

A bar of wrought iron, when its texture is examined in the mode pointed out by Mr. Daniell, presents a fasciculated appearance, the fibres running in a parallel and unbroken course throughout its length. This structure may be well seen by tearing a bar of wrought iron asunder.

758. Steel is a compound of iron with carbon, the proportions being variable. It combines the fusibility of cast with the malleability of bar iron, and when heated and suddenly cooled it becomes very hard, whence its superiority for the manufacture of cutting instruments. If kept for a long time in fusion, it loses carbon and becomes pure iron.

Iron is converted into steel by a process called *cementation*, which consists in heating bars of the purest iron in contact with charcoal: it absorbs carbon and increases in weight, at the same time acquiring a *blistered* surface. This, when drawn down into smaller bars and beaten, forms *tilted steel;* and this broken up, heated, welded, and again drawn out into bars, forms *shear steel. English cast steel* is prepared by fusing blistered steel with a flux composed of carbonaceous and vitrifiable ingredients, casting it into ingots, and afterwards, by gentle heating and carefully hammering, giving it the form of bars.

759. Messrs. Stodart and Faraday found, that by intensely heating pure steel with charcoal powder, a *carburet of iron*, of a dark grey colour, very brittle and highly crystalline, was formed, which afforded, upon analysis,

94.36	iron
5.64	carbon
100	

In this compound, which was frequently made and afforded the same results on analysis, and which therefore may be regarded as definite, the proportion of carbon very far exceeds that in steel, so that the latter is probably a compound of pure iron with a variable proportion of the true carburet.

760. The following table, drawn up by Mr. Mushet, shows the quantities of charcoal which disappeared during the conversion of iron into the different *subcarburets of iron* known in commerce.—*Phil. Mag.* xiii. :

Charcoal absorbed.	RESULTS.
$\frac{1}{120}$	soft cast steel
$\frac{1}{100}$	common cast steel
$\frac{1}{90}$	the same, but harder
$\frac{1}{50}$	the same: too hard for drawing
$\frac{1}{33}$	white cast iron
$\frac{1}{30}$	mottled cast iron
$\frac{1}{25}$	black cast iron

When the carbon amounts to $\frac{1}{66}$ of the whole mass, the hardness is at a maximum.

761. *Wootz* or *Indian steel* is truly valuable for the purpose of making edge tools. Its peculiar excellence is owing to combination with a minute portion of the earths alumina and silica; or rather, perhaps, with the bases of these earths. (*Quarterly Journal of Science*, vii., 288.) Whether the earths are found in the ore, or are furnished by the crucible used in making the steel, is not certainly known; nor is

the Indian steel-maker probably aware of their presence. Wootz, in the state in which it is imported, is not fit to make into fine cutlery. It requires a second fusion, by which the whole mass is purified and equalized, and fitted for forming the finest edge instruments.

762. The texture of steel, as exhibited by the action of an acid, is not fibrous, but appears somewhat lamellated.

763. When steel is heated to a cherry-red colour, and then plunged into cold water, it becomes so extremely hard and brittle, as to be unfit for almost any practical purpose. To reduce it from this extreme hardness, is called by the workmen *tempering*, and is effected by again heating the steel to a certain point. The surface being a little brightened exhibits, when heated, various colours which constantly change as the temperature is increased, and by these colours it has been customary to judge of the temper of the steel.

A more accurate as well as convenient method is to use a bath and thermometer; the bath may be of mercury, or of the fusible mixture of lead, tin, and bismuth, or, indeed, of any fluid whose boiling point is not much under 600°. Into this bath the articles to be tempered are put, together with the bulb of a thermometer graduated to near the boiling point of mercury. The corresponding degrees at which the various colours appear are from 430° to 600°. The first change is at about 430°, but this is too faint to be distinguished, except by comparison with another piece of untempered polished steel. At 460° the colour is straw, becoming deeper as the temperature is increased; at 500° the colour is brown; this is followed by a red tinge with streaks of purple, then purple, and at nearly 600° it is blue.

The degrees at which the respective colours are produced being thus known, it follows that the workman has only to heat the bath, with its contents up to the required point. For example, suppose the blade of a penknife (or one hundred of them) to require tempering: they are suffered to remain in the bath until the mercury in the thermometer rises to 460°, and no longer, that being the heat at which the knife (supposing it to be made of the best English cast steel) will be sufficiently tempered.

The advantages attending this method are obvious: the heat is equally applied to the whole; and the workman, instead of attending to the colour of each blade, has only to observe the thermometer.

Some recent experiments, proving that steel, for certain uses, is sufficiently tempered long before it is heated to produce any change of colour, promise to give additional value to this process by a thermometer. The knife edges attached to the pendulum described by Capt. Kater, *Phil. Trans.*, 1818, p. 38.) were forged by Mr. Stodart, from a piece of fine wootz. They were carefully hardened, and tempered in the bath at 430°; on trial they were found too soft. They were a second time hardened, and then heated to 212°. The intention was to increase the heat from that point, trying the temper at the advance of about every ten degrees. In the present instance this was not necessary, the heat of boiling water proving to be the exact point, at which the knife edges were admirably tempered.

It is highly probable that steel, for many uses, may be sufficiently tempered in a range so extensive, as from 212° to 430°, and, by the thermometer, all the intervening degrees may certainly be ascertained.

That the colour produced on the surface of heated steel is the effect of oxidation, is proved from the circumstance that when steel is heated and suffered to cool under mercury or oil, none of the colours appear; nor do they when it is heated in hydrogen or in nitrogen.

764. Steel is improved by combination with some other of the metals, forming valuable alloys. (See SILVER.) They seem to require some difference in treatment from the workman, particularly in tempering.—*Quarterly Journal of Science*, Vol. ix. p. 319.

SECTION X. *Zinc.*

765. ZINC is found in the state of oxide and of sulphuret. It may be obtained pure by dissolving the zinc of commerce in dilute sulphuric acid, and immersing a plate of zinc for some hours in the solution, which is then filtered, decomposed by carbonate of potassa, and the precipitate ignited with charcoal in an iron or earthen retort.

Common zinc generally contains a portion of lead, copper, iron, traces of arsenic and manganese, and a little plumbago: these impurities remain in the form of a black powder when it is dissolved in dilute sulphuric acid.

Zinc is a bluish white metal, specific gravity 7, malleable at 300°, but very brittle when its temperature approaches that of fusion, which is about 680°. It is somewhat ductile, but its wire possesses little tenacity.

766. *Oxide of Zinc* is obtained by heating the metal exposed to air. At a red heat it takes fire, burns with a bright flame, and is converted into a white flocculent substance, formerly called *pompholix*, *nihil album*, *philosopher's wool*, and *flowers of zinc*. It consists of 34 zinc + 8 oxygen[*]. This oxide is white, tasteless, and soluble in the alcalis. As prepared by combustion it contains small particles of the metal, which always render it gritty; hence, for pharmaceutical use, it is best prepared by precipitating solution of sulphate of zinc by ammonia, and washing and drying the precipitate. It is sometimes used as a pigment, both with oil and water; and is employed in medicine as a tonic, and as an external application.

767. The representative number of zinc was obtained by dissolving 100 grains of pure zinc in nitric acid, evaporating to dryness and keeping the residue at a dull red heat till it ceased to lose weight: 122.75 grains of oxide of zinc were thus obtained, and 22.75 : 100 : : 8 : 35.1.

768. *Chloride of Zinc* is formed by heating leaf zinc in chlorine, or by evaporating muriate of zinc to dryness, and heating the residue red-hot in a glass tube. It is a fusible compound, very deliquescent, and produces a *muriate of zinc* by the action of water. It does not rise at a red heat in close vessels. It consists of 35.5 zinc + 36 chlorine. It was formerly called *butter of zinc*.

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[*] This is deduced from Thomson's late experiments (see Ann. Ph. vol. 17, for April 1821) as it has been shown elsewhere that 8 and not 7.5 is the representative number of oxygen, it follows that 33 the number deduced from Brand's data can not be correct but if we merely substitute 8. for 7.5; zinc will be 35 which does not agree with the composition by Thomson.

The attraction of zinc for chlorine is very great, and this metal may therefore often be employed for separating chlorine from other combinations.

769. *Chlorate of Zinc* crystallizes in octoëdra, and is a very soluble salt.

770. *Muriate of Zinc* is very soluble and difficultly crystallizable: heated in the air it loses muriatic acid and leaves oxide of zinc: in a close vessel it loses water and leaves chloride of zinc.

771. *Iodine and Zinc* readily combine, and produce a fusible, volatile, and crystalline compound, which, when exposed to air, deliquesces into *hydriodate of zinc.*

The iodide consists of 34 zinc + 125 iodine; and the hydriodate may be regarded as consisting of one proportional oxide of zinc = 42 + one proportional hydriodic acid = 126.

772. *Iodate of Zinc.*—When iodate of potassa is added to solution of sulphate of zinc, it forms an insoluble iodate of zinc.

773. *Nitrate of Zinc* is a deliquescent salt, which crystallizes with difficulty in four-sided prisms. They are copiously soluble in water and alcohol, and consist of

42 oxide
54 nitric acid
—
96

774. Liquid ammonia readily dissolves oxide of zinc, and even acts upon the metal. The concentrated solution of the oxide furnishes feathery crystals; it is decomposed by the acids, and the immersion of a plate of copper causes a precipitation of part of the zinc, the ammonia, acquiring at the same time a blue colour.—De Lassone, *Annales de Chimie*, xxxv. 53.

775. *Sulphuret of Zinc* exists native under the name of *Blende.* It may be formed artificially by heating oxide of zinc with sulphur, and is then of a yellow brown colour. It consists of 34 zinc + 16 sulphur.

Blende is a brittle soft mineral, of different shades of brown and black. Its primitive form is the rhomboidal dodecaëdron. It usually contains traces of iron and lead. It is an abundant mineral, and important as a source of the pure metal, which is obtained by roasting the ore, and afterwards exposing it to heat in proper distillatory vessels, mixed with charcoal (783). The English miners call it *black jack.*

776. *Hyposulphite of Zinc* was formed long ago by Fourcroy, who considered it as a *sulphuretted sulphite.* He formed it by digesting metallic zinc in sulphurous acid, sulphuretted hydrogen is disengaged, and by gentle evaporation crystals are obtained, which are to be digested in alcohol; this liquid dissolves the hyposulphite, and affords it in prismatic crystals. A mixture of oxide of zinc and sulphur treated by sulphurous acid affords the same salt; it is efflorescent, and easily decomposed by heat.—Fourcroy, *Systême des connoissances Chymiques*, v. 380.

777. *Sulphite of Zinc* is easily formed by dissolving the oxide in sulphurous acid; it is more easily crystallizable than the hyposulphite, and is insoluble in alcohol.

778. *Sulphate of Zinc.*—The metal is readily oxidized and dissolved

by dilute sulphuric acid, hydrogen gas is given off, and a transparent colourless solution of sulphate of zinc results, which, by evaporation, affords crystals in the form of four-sided prisms, terminated by four-sided pyramids.

This salt is soluble in 2.5 parts of water at 60°. It consists of 1 proportional of oxide = 42 + 1 proportional of acid = 40. Its crystals contain 7 proportionals of water = 63. Sulphate of zinc is prepared for the purposes of the arts from the native sulphuret, and is usually in the form of a white amorphous mass, called *white vitriol.*

Native Sulphate of Zinc is found at Holywell in Flintshire, and in other places where the sulphuret of zinc occurs; it is probably the result of the decomposition of that ore.

779. *Phosphuret of Zinc* is a brilliant lead-coloured compound.

780. Neither *Hypophosphite* nor *Phosphite of Zinc* have been examined.

781. *Phosphate of Zinc* is not crystallizable. It may be obtained by dissolving zinc in phosphoric acid, and evaporation to dryness. A phosphate of zinc is also precipitated upon the addition of phosphate of soda to sulphate of zinc. These salts have not been precisely examined, but it is probable there is a phosphate and a bi-phosphate of zinc.

782. *Carbonate of Zinc* occurs native, forming one of the varieties of the mineral called *calamine.* It may be formed by adding carbonate of potassa to sulphate of zinc. It consists of 42 oxide of zinc + 22 carbonic acid = 64. It is white and tasteless.

The primitive form of calamine, which occurs both crystallized and massive, is an obtuse rhomboid. It is often found investing carbonate of lime, which has sometimes been decomposed, and the calamine remains in pseudo-crystals. This mineral abounds in Somersetshire, Flintshire, and Derbyshire. A beautiful variety, coloured by carbonate of copper, is found at Matlock. A variety of calamine, containing siliceous earth, is known by the name of *electric calamine*, from its property of becoming electrical when gently heated.

783. The zinc of commerce is procured from the native sulphuret and from calamine by the following process. The ore is first picked and broken into small pieces, and then submitted to a dull red heat in a reverberatory furnace, by which carbonic acid is driven off from the calamine, and sulphur from the blende. It is then washed, ground, and thoroughly mixed with about one eighth its weight of powdered charcoal. This mixture is put into large earthen pots, not unlike oil jars, six of which are usually placed in a circular furnace; each pot has an iron tube passing from its lower part, through the floor of the furnace, and dipping into water; they are every where else firmly luted: upon the application of a red heat, the metal distils through the tube into the water beneath, whence it is collected, melted, and cast into cakes.

784. *Borate of Zinc* is an insoluble white powder.

785. Ferrocyanate of potassa produces a yellowish white precipitate in solutions of zinc.

786. The salts of zinc are mostly soluble in water, and the solutions are colourless and transparent: they are not precipitated by hydriodic acid. Potassa, soda, and ammonia, form white precipitates, soluble in excess of the alcali, and sulphuric acid. Hydrosulphuret of ammonia

produces a yellowish white precipitate. The soluble phosphates, carbonates, and borates, produce white precipitates.

787. *Alloys of Zinc.*—With potassium and sodium zinc forms brittle alloys, decomposable by exposure to air and water. Its alloy with manganese is unknown. With iron it forms a white and somewhat malleable alloy, which is difficult to form; but if plates of hot iron be dipped into melted zinc, they acquire the appearance of tin-plate.

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SECTION XI. *Tin.*

788. THIS metal has been known from the remotest ages. It was in common use in the time of Moses, and was obtained at a very early period from Spain and Britain, by the Phœnicians.—PLINY, lib. iv. cap. 34, and xxxiv. cap. 47.

The native oxide is the principal ore of tin; the metal is obtained by heating it to redness with charcoal. The process is described at length in AIKIN's *Dictionary*, (*Art.* TIN.)

Tin has a silvery white colour; it is malleable, though sparingly ductile. Specific gravity 7.30. It melts at 440°, and by exposure to heat and air is gradually converted into a white peroxide. Placed upon ignited charcoal under a current of oxygen gas, it burns very brilliantly.

789. A preparation under the name of *powdered tin* is sometimes directed to be prepared for pharmaceutical use, by shaking the melted metal in a wooden box rubbed with chalk on the inside: *tin filings* have also a place in some *Pharmacopœiæ*, and have been used as a vermifuge. These preparations are, however, both dangerous, the metal being rendered poisonous in the former case by slight oxidation, (ORFILA, *Traité des Poisons*, T. i. 2me partie, p. 18.) and often creating very dangerous irritation when given in filings.

790. *Protoxide of Tin* is obtained by precipitating protomuriate of tin by ammonia; it falls in the state of hydrate; when dried, it is of a grey colour, and undecomposable by heat. It dissolves in the alcalis; exposed to heat and air it passes into the state of peroxide, undergoing a faint combustion. Its ammoniacal solution, when long kept, deposits metallic tin in arborescent crystals, and becomes a solution of the peroxide.

791. *Peroxide of Tin* is formed by treating the metal with nitric acid: there is a violent action attended by the formation of nitrate of ammonia. (287). Scarcely any of the metal is dissolved, but remains as a yellowish powder, which may be purified by washing. It is also formed by heating tin filings with red oxide of mercury; and by projecting a sufficient quantity of nitre upon red-hot tin. This oxide dissolves in the alcalis. Fused with glass it forms *White Enamel*. Heated intensely it becomes insoluble in acids, and undergoes fusion.

The substance called *Tin Putty*, is an oxide of tin formed by levigating the crusts of oxide that form upon the metal when kept for some time in fusion.

792. *Native Oxide of Tin* is found in Cornwall; in Spain; and in

Saxony: it has also been found in Brittany, in France; in the East Indies; and in South America. The specific gravity of the native oxide is 7: Its primitive crystal is an obtuse octoëdron, of which the modifications are extremely numerous. (W. PHILLIPS, *Geological Transactions*, Vol. ii.) In some of the valleys of Cornwall, tin is found in rounded nodules, of various sizes, mixed with pebbles and rounded fragments of rocks. To separate the tin from the alluvial matter, currents of water are passed over it, and hence these deposits have been called *stream works*, and the tin ore, *stream tin*. One of the most extensive of these is a branch of Falmouth Harbour.

A modification of stream tin is called *wood* tin. It usually appears in small banded fragments of globular masses.

793. The number representing tin is 59. The protoxide consists of 59 tin + 8 oxygen. The hydrate of 67 protoxide + 9 water; and the peroxide of 59 tin + 16 oxygen. These numbers are deduced from the accurate analyses of Dr. John Davy (*Phil. Trans.* 1812) and M. Gay-Lussac. (*Annales de Chimie*, lxxx.) The protoxide of tin, according to both these chemists, consisting of 100 tin + 13.5 oxygen; and the chloride, according to John Davy, of 100 tin + 60.71 chlorine.

794. *Chloride of Tin* is procured by heating together an amalgam of tin and calomel; or more simply by heating protomuriate of tin in a retort till it fuses; it is a grey semi-transparent crystalline solid, which dissolves in water, forming a protomuriate of tin; it is volatile at a red heat; it consists of 59 tin + 36 chlorine. Heated in chlorine it burns into perchloride of tin.

795. If tin be heated in chlorine, or if amalgam of tin be distilled with corrosive sublimate, a *perchloride* is obtained. The best proportions are six parts of tin, previously combined with one of mercury, and intimately mixed with thirty of corrosive sublimate. The mixture is put into a glass retort with a sufficiently capacious receiver luted to it, and may de distilled over a small charcoal fire. The heat should be slowly raised to prevent too sudden action. Towards the end of the process a little chloride rises, which the old chemists, from its consistency and appearance, called *Butter of Tin*. It is a transparent colourless fluid, and when poured into water, is instantly converted into permuriate of tin. It consists of 59 tin + 72 chlorine. It was formerly called *Libavius's Fuming Liquor*: it exhales copious fumes when exposed to a moist air, and produces muriatic acid and oxide of tin. It is instantly decomposed by metallic zinc, forming chloride of zinc and a precipitate of metallic tin.

796. *Chlorate of Tin* has not been examined.

797. The *Protomuriate of Tin*, used by dyers, may be obtained by boiling one part of tin with two of muriatic acid. This solution quickly absorbs oxygen from the air and from several compounds, and if added to certain metallic solutions, revives or deoxidizes them. With solution of gold it produces a purple precipitate used in painting porcelain, and known under the name of *Purple of Cassius*. It crystallizes from its concentrated solution in small deliquescent needles. With infusion of cochineal it produces a purple precipitate. This muriate of tin is the *Sal Jovis* of old writers, Jupiter being the name by which the alchymists distinguished this metal.

When potassa is added to muriate of tin, a *submuriate* of the protoxide is thrown down, containing, according to J. Davy,

70.4	protoxide
19	muriatic acid
10.6	water
100.0	

798. The *Permuriate of Tin* (muriate containing the peroxide) may be formed by dissolving the metal in nitro-muriatic acid, or by exposing the muriate to air. It forms acicular crystals in the upper parts of phials containing the bi-chloride imperfectly secured from air; and is directly formed by adding water to the bi-chloride, which excites much heat, and forms a concrete mass easily fusible and soluble in water. It does not occasion precipitates in the metallic solutions, and produces a scarlet colour with infusion of cochineal.

799. The pure alcalis added to this salt of tin, occasion a precipitate which has not been accurately examined, but is said to be a *subpermuriate*. The peroxide of tin is more readily soluble in alcalis than the protoxide; it has been hence termed *Stannic Acid*.

800. *Iodide of Tin* may be formed directly by heating the metal with iodine; or indirectly by adding hydriodic acid to a solution of muriate of tin. It is an orange-coloured compound, and has not been analyzed.

801. *Iodate of Tin* has not been examined.

802. *Nitrate of Tin* may be formed by acting upon the metal by dilute nitric acid; a yellow solution which will not crystallize is obtained; exposed to air it absorbs oxygen, and peroxide of tin precipitates. If evaporated the peroxide falls, and a portion of nitrate of ammonia is formed. It is evident therefore that part of the water, as well as of the acid, are here decomposed.

803. *Tin and Sulphur.*—There are two sulphurets of tin. That containing 1 proportional of metal + 1 of sulphur, may be procured by heating tin with sulphur; it is of a deep bluish colour and crystallizes in long needles.

804. *Bi-sulphuret of Tin* is of a bright golden yellow colour, and flaky structure, and has been termed *Aurum Musivum*. It is formed by heating peroxide of tin with its weight of sulphur. Mr. Woulfe has given a formula for its production, (*Phil. Trans.*, 1771) but the following, taken from the *London New Dispensatory* of 1765, answers best. Take 12 oz. of tin and amalgamate it with 6 oz. of mercury, reduce it to powder, and mix it with 7 oz. of flowers of sulphur and 6 oz. of sal ammoniac and put the whole into a glass matrass placed in a sand heat. Apply a gentle heat till the white fumes abate, then raise the heat to redness, and keep it so for a due time. On cooling and breaking the matrass, the *Mosaic gold* is found at the bottom.—*See* WOULFE's *Paper, and* AIKIN's *Dict.: Art.* Tin.

The sulphurets of tin consist respectively of 59 tin + 16 sulphur, and 59 tin + 32 sulphur.

805. *Hyposulphite of Tin*, has not been examined. Muriate of tin forms no precipitate with the alcaline hyposulphites.

806. *Sulphite of Tin* is formed by digesting the protoxide in sulphurous acid, but the salt has not been examined.

807. *Sulphate of Tin.*—When tin is boiled in sulphuric acid, a solution is obtained which deposits white acicular crystals. A protosulphate of tin is also precipitated by pouring sulphuric acid into protomuriate of tin.

808. *Hydrosulphuretted Oxide of Tin* is yellow brown, and formed by pouring solution of sulphuretted hydrogen into dilute muriate of tin.

809. *Phosphuret of Tin* may be formed by dropping phosphorus into melted tin. It is of a silvery colour, sectile, and somewhat ductile. When its filings are sprinkled upon hot coals the phosphorus burns.

810. *Phosphite of Tin* has not been examined.

811. *Phosphate of Tin* is formed by adding phosphate of soda to the solutions of tin. It is a white powder, not soluble in water, and fuses at a red heat into an opaque white enamel.

812. *Carbonate of Tin.*—When carbonate of potassa is added to protomuriate of tin, a white precipitate ensues, which, when washed and dried, effervesces copiously with the acids.

813. *Borate of Tin* is an insoluble white powder.

814. Ferrocyanate of potassa produces a white precipitate in solution of muriate of tin.

815. The salts of tin are mostly soluble in water. They are precipitated, of an orange colour by hydriodic acid, and by hydrosulphuret of ammonia, provided no excess of acid be present. Solution of muriate of gold, and of corrosive sublimate produce purple and black precipitates in the salts of tin containing the protoxide, but none in those containing the peroxide.

816. *Alloys of Tin.*—With potassium and sodium tin forms brittle white alloys. Its alloy with manganese is not known. It does not readily combine with iron, but tin-plate (756) may be considered as an imperfect alloy of those metals. With zinc it forms a hard brittle alloy.

SECTION XII. *Cadmium.*

817. THIS metal is contained in certain ores of zinc, and especially in the black fibrous Blende of Bohemia. It may be procured by digesting the ore in muriatic acid, by which a mixed muriate of zinc and cadmium is obtained: it should be evaporated to dryness, and re-dissolved in water. If cadmium be present, the solution affords a bright yellow precipitate with sulphuretted hydrogen; and upon immersing into it a plate of zinc, metallic cadmium is precipitated, which may be fused into a button in the usual way.

The simplest method of detecting cadmium is the following, devised by Dr. Wollaston. Digest the ore in muriatic acid, filter, and evaporate to dryness: re-dissolve the dry mass in water, filter, and put a cylinder of iron into the clear solution to precipitate all metals thus separable; filter again, and immerse a cylinder of zinc, which will throw down metallic cadmium, and which, when re-dissolved in muriatic acid exhibits its peculiar characters.

818. The physical properties of cadmium closely resemble those of tin: its specific gravity is 8.63. It fuses and volatilizes at a temperature a little below that required by tin. Air does not act upon it except when heated, when it forms an orange-coloured oxide, not volatile, and easily reducible.

819. *Oxide of Cadmium* readily dissolves in acids; it is precipitated by potassa in the state of a white hydrated oxide, soluble in ammonia. Sulphuretted hydrogen forms a yellow precipitate in the solution of cadmium, and zinc throws down metallic cadmium.

From the experiments of Mr. Children, it appears that the oxide contains

Cadmium	88
Oxygen	8

Consequently, the representative number of the metal will be 88. The other compounds of cadmium have scarcely been examined[*].

SECTION XIII. *Copper*.

820. THIS metal is found native, and in various states of combination. Of its ores, the oxide, chloride, sulphuret, sulphate, phosphate, carbonate, and arseniate, are the most remarkable. The metal may be obtained perfectly pure by dissolving the copper of commerce in muriatic acid; the solution is diluted, and a plate of iron is immersed upon which the copper is precipitated. It may be fused into a button, after having been previously washed in dilute sulphuric acid to separate a little iron that adheres to it.

It was known in the early ages of the world, and was the principal ingredient in domestic utensils, and in the instruments of war, previous to the discovery of malleable iron. The word *copper* is derived from the island of Cyprus, where it was first wrought by the Greeks.

821. Copper has a fine red colour and much brilliancy; it is very malleable and ductile, and has a peculiar smell when warmed or rubbed. It melts at a cherry red or dull white heat. Its specific gravity is 8.89. Under a flame, urged by oxygen gas, it takes fire, and burns with a beautiful green light.

822. Exposed for a long time to damp air, copper becomes covered with a thin greenish crust of carbonate. If heated and plunged into water, a quantity of reddish scales separate, consisting of an imperfect oxide. The same scales fly off during cooling from a plate of the metal which has been heated red hot.

823. *Native Copper* occurs in a variety of forms; massive, dendritic, granular, and crystallized in cubes, octoëdra, &c. It is found in Cornwall, Siberia, Saxony, Hanover, Sweden, and America; chiefly, but not exclusively, in primitive rocks.

824. *Copper and Oxygen.*—There are two oxides of copper. The red or *Protoxide* occurs native. It may be formed artificially, by digesting a mixture of metallic copper, and peroxide of copper, in muriatic acid. When potassa is added to this solution, a *hydrated protoxide*, of an orange colour, falls; if quickly dried out of the contact of

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[*] In a subsequent part of this work Brande gives the atom of Cadmium = 52.3 which equivalent he also introduces into his tables, see article Cadmium, section xii. and the tables. This 52.3 requires to be altered to 55.8 (nearly) so as to be proportional to 8 oxygen, instead of 7.5.

air, it becomes of a red brown: it consists of 64 copper + 8 oxygen = 72.

825. The *Native Protoxide*, or *Ruby Copper*, is of a red or steel-grey colour, soft and brittle, and occurs massive, and crystallized in octoëdra, dodecaëdra, and cubes. There is a beautiful variety in fine capillary crystals; and another, which is compact and earthy, called *Tile Ore*. Cornwall abounds in fine specimens of this ore.

826. *Peroxide of Copper* is procured by precipitating nitrate of copper by potassa, washing the precipitate and exposing it to a red heat. It is black, and consists of 64 copper + 16 oxygen = 80.

827. The composition of this oxide is learned by dissolving 100 grains of pure copper in nitric acid, evaporating to dryness, and giving the residue a red heat in a porcelain crucible; it is peroxide of copper, and weighs 125 grains: considering this as a compound of 1 proportional of copper and 2 of oxygen, the number 64 will represent the metal; for, 25 : 100 : : 16 : 64.

100 grains of pure native protoxide of copper in octoëdral crystals, dissolved in muriatic acid, furnished a precipitate of 89 grains of metallic copper upon a plate of iron, so that the protoxide consists of 89 copper + 11 oxygen; and 11 : 89 : : 8 : 64.7.

This number closely accords with that derived from the analysis of the chloride.

828. *Copper and Chlorine.*—Gaseous chlorine acts upon copper with great energy, and produces two chlorides; the one a fixed fusible substance, which is the protochloride, consisting of 1 proportional of copper = 64 + 1 proportional of chlorine = 36. The other a volatile yellow substance, which is a perchloride, and contains 64 copper + 72 chlorine.

829. The *Protochloride of Copper* was first described by Boyle in 1666, under the name of *Rosin of Copper*. It may be obtained by exposing copper filings to the action of chlorine not in excess; or by evaporating the protomuriate, and heating the residue in a vessel with a very small orifice; or by heating the perchloride in the same way. It is also the residue of the distillation of a mixture of two parts of corrosive sublimate and one of copper filings. It is insoluble in water, but soluble in muriatic acid, from which potassa throws down a protoxide. When water is added to its muriatic solution it is precipitated unaltered; its colour varies, being generally dark brown; but if fused and slowly cooled, it is yellow, translucent, and crystalline.

830. When moistened chloride of copper is exposed to air it acquires a greenish white colour, and becomes converted into a *subpermuriate of copper*. The same compound may be formed by adding hydrated peroxide of copper to a solution of the permuriate; or by exposing to the atmosphere slips of copper partially immersed in muriatic acid. This compound consists of

2	proportionals peroxide of copper 80 × 2 =	160
1	———— muriatic acid	37
2	———— water	18
		215

831. *Perchloride of Copper* may be formed by dissolving peroxide of copper in muriatic acid, and evaporating to dryness by a heat below

400°. It is soluble in water, producing a permuriate, from which potassa precipitates the peroxide: its colour is yellow, but it becomes white and afterwards green when exposed to heat and moisture. Exposed to a red heat in a tube with a very small orifice, gaseous chlorine is expelled and it becomes a protochloride.

832. Muriatic acid acts with difficulty on metallic copper, except it be concentrated and boiling; but it readily dissolves the peroxide, forming a brown or grass-green solution, according to its state of dilution. This is a *permuriate of copper*. If plates of copper be exposed to the joint action of air and the fumes of muriatic acid, they become incrusted with a green powder, which is readily soluble in muriatic acid, and which may be termed a *subpermuriate*. (830.)

If metallic copper be digested in muriatic acid with the peroxide, an olive-coloured solution of *protomuriate of copper* is formed which strongly attracts oxygen, and which when concentrated deposits small grey crystals. The addition of potassa occasions a precipitate of the orange or protoxide of copper, (824) which according to Berzelius, consists of 100 copper + 12.5 oxygen. (*Annales de Chim.*, lxxviii. 107.) Proust's analysis of the peroxide gives 100 copper + 25 oxygen, and these numbers furnish 64 as the equivalent of copper. (827.)

833. *Native Submuriate of Copper* is found in Peru and Chili, sometimes in the form of green sand, and sometimes massive and crystallized. The green sand was found in the river Lipas, in the desert of Atacama, separating Peru from Chili, hence mineralogists have termed this variety, *Atacamite*. Muriate of copper has also been found upon some of the lavas of Vesuvius. The primitive form of this substance is an octoëdron. It is of a deep green colour, and contains, according to Dr. Davy's analysis,

73	peroxide of copper
16.2	muriatic acid
10.8	water
100	

834. *Chlorate of Copper* is a blue-green deliquescent salt, difficultly crystallizable, formed by dissolving peroxide of copper in chloric acid. A piece of paper dipped into its solution burns with a remarkably green flame.—Vauquelin.

835. An *Iodide of Copper* is precipitated from solutions of the metal by hydriodic acid. It is brown and insoluble.

836. When solution of iodate of potassa is added to solutions of copper, an insoluble *iodate of copper* is thrown down.

837. *Nitrate of Copper.*—Nitric acid, diluted with three parts of water, rapidly peroxidizes copper, evolving nitric oxide, and forming a bright blue solution, which affords deliquescent prismatic crystals on evaporation, of a fine blue colour and very caustic. It consists of 80 peroxide + 108 acid; but the crystals contain a considerable portion of water, which causes them to liquefy at a temperature below 212°. At a higher temperature they lose water and acid, and according to Proust become a *sub pernitrate*, which is insoluble in water, and entirely decomposed at a red heat. There appears to be no protonitrate of copper, for protoxide of copper, digested in very dilute nitric acid is resolved into peroxide which dissolves, and into metallic copper. Po-

tassa forms, in this solution, a bulky blue precipitate of *hydrated peroxide of copper*, which, when boiled in potassa or soda, becomes black from the loss of its combined water.

838. When crystals of nitrate of copper are coarsely powdered, sprinkled with a little water, and quickly rolled up in a sheet of tinfoil, there is great heat produced, nitrous gas is rapidly evolved, and the metal often takes fire.

839. If ammonia be added to solution of nitrate of copper, it occasions a precipitate of the hydrated peroxide; but if it be added in excess, the precipitate is re-dissolved, and a triple *ammonio-nitrate of copper* is produced.

840. If peroxide of copper be digested in ammonia it is dissolved, forming a bright blue solution, which by careful evaporation affords fine blue crystals. A mixture of lime, sal ammoniac, and water, placed in a copper vessel, or mixed with oxide of copper, also affords a fine blue liquor in consequence of the action of the ammonia on the oxide of copper. This solution is the *Aqua Sapphirina* of old pharmacy. The compound has sometimes been called *Ammoniuret of Copper*, or *Cuprate of Ammonia*.

841. The protoxide of copper also dissolves in ammonia, but the solution is colourless; if it be exposed to air it becomes blue. This may be well shown by filling a tall glass with liquid ammonia, and adding a few drops of solution of protomuriate of copper; the liquid presently acquires a blue colour upon the surface, but remains for some time colourless below.

842. Plates of copper digested in a solution of muriate of ammonia, are soon incrusted with a green powder, which has been used in the arts under the name of *Brunswick green*.

843. *Copper and Sulphur.*—There are two sulphurets of copper, both of which exist native; the one is black, and may be formed artificially, by heating a mixture of copper filings and sulphur: as soon as the latter melts a violent action ensues, the copper becomes red hot, hydrogen escapes, and a black brittle body is formed, consisting of 64 copper + 16 sulphur*.

The *bi-sulphuret* is a common ore of copper, called *pyrites*. It consists of 64 copper + 32 sulphur, and is of a golden yellow colour.

844. The *Native Black Sulphuret of Copper* is principally found in primitive countries. In England, it occurs in great beauty, crystallized and massive, in Cornwall, and in Yorkshire. Its colour is grey; its lustre shining and metallic, and it yields easily to the knife. Its primitive form is a six-sided prism, which passes into the dodecaëdron with triangular faces, and various modifications of it.

A variety of black sulphuret of copper, containing iron and arsenic, has been described by Messrs. W. and R. Phillips. It has been termed by the latter *Tennantite;* its most ordinary form is the rhomboidal dodecaëdron, either perfect or variously modified.—*Quarterly Journal of Science and Arts*, Vol. vii., p. 95.

845. *Copper pyrites*, or the yellow sulphuret of copper, is the most important and generally occurring ore, from which the largest proportion of the copper of commerce is derived; it occurs in a variety of

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* The hydrogen appears to be derived from the sulphur. (343.)

forms, its primitive crystal being the regular tetraëdron. The Cornish mines are very productive of this ore, and it is the principal product of of the Parys mountain mine in Anglesea. A beautiful iridescent variety occurs in the Ecton mine in Staffordshire.

846. The following is an outline of the process by which these ores of copper are reduced, as carried on upon a very large scale near Swansea, where the chief part of the Cornish ores are brought to the state of metal. The ore, having been picked and broken, is heated in a reverberatory furnace, by which arsenic and sulphur are driven off. It is then transferred to a smaller reverberatory, where it is fused, and the slag which separates, being occasionally removed, is cast into oblong masses used as a substitute for bricks. The impure metal collected at the bottom of the furnace is granulated by letting it run into water; it is afterwards re-melted and granulated two or three times successively, in order further to separate impurities, which are chiefly sulphur, iron, and arsenic, and ultimately cast into oblong pieces called *pigs*, which are broken up, roasted, and lastly melted with a portion of charcoal in the refining furnace. It is now malleable: and is generally rolled into plates, which are annealed, and when hot, quenched in urine, which gives the metal a peculiar red tinge.

847. *Hyposulphite of Copper* was formed by Mr. Herschel by mixing hyposulphite of potassa with sulphate of copper. It is colourless; of an intensely sweet taste; and provided air be excluded, it is not turned blue by ammonia, which seems to show that the metal is in the state of protoxide.—*Edinburgh Philosophical Journal*, i. 24.

848. *Sulphite of Copper* may be obtained by passing sulphurous acid into water through which oxide of copper is diffused. Small red crystals are formed, composed of protoxide of copper and sulphurous acid. —CHEVREUIL, *Annales de Chimie*, lxxxiii.

849. When sulphite of potassa is added to nitrate of copper a precipitate falls, which assumes the form of red and yellow crystals. The former are sulphite of copper; the latter a tripple *sulphite of potassa and copper*.—CHEVREUIL.

850. *Persulphate of Copper—Roman Vitriol—Blue Vitriol.*—This salt is formed by dissolving peroxide of copper in sulphuric acid. It crystallizes in rhomboidal prisms of a fine blue colour, doubly refractive, and soluble in about 4 parts of water at 60°. It may also be formed by boiling copper filings in sulphuric acid; a process which furnishes abundance of sulphurous acid, but which is not generally had recourse to, to produce sulphate of copper. It is made upon a large scale, by exposing roasted sulphuret of copper to air and moisture. When heated it loses water of crystallization, and at a higher temperature sulphuric acid is evolved, unmixed with sulphurous acid, as in the case of the decomposition of protosulphate of iron (738), and peroxide of copper remains. It is the *Vitriol* or *Salt of Venus* of the alchymists. It consists of 80 peroxide + 80 sulphuric acid; when crystallized it contains 10 proportionals of water, and consequently its composition will stand thus:—

1 proportional of peroxide	80
2 proportionals of sulphuric acid .	80
10 proportionals of water	90
	250

There appears to be no *protosulphate* of copper, for when protoxide of copper is digested in dilute sulphuric acid, metallic copper is separated, and a solution of the peroxide obtained.

851. By cautiously adding ammonia to a solution of the foregoing salt, a *subsulphate of copper* is precipitated, consisting of 160 oxide + 40 acid. The alcalis precipitate hydrated peroxide from the solution of the persulphate, and excess of ammonia forms a *triple sulphate of ammonia and copper.* The same compound is formed by triturating carbonate of ammonia with crystals of sulphate of copper. It is the *cuprum ammoniatum* of the *Pharmacopœia.*

852. *Sulphate of Copper and Potassa* is a triple salt formed by digesting peroxide of copper in bisulphate of potassa. It crystallizes in rhomboids of a pale blue colour.

853. *Phosphorus and Copper* form a grey brittle phosphuret. It is most easily made by dropping pieces of phosphorus on red-hot copper wire. It is more fusible than copper.

854. Neither the *hypophosphite* nor *phosphite of copper* have been examined.

855. *Phosphate of Copper* may be formed by mixing solution of sulphate of copper with phosphate of soda; it is a bluish green insoluble powder, composed, as would appear from Mr. Chenevix's analysis, (*Phil. Trans*,. 1803.) of

1 proportional	peroxide of copper	80
2 ————	phosphoric acid . .	56
1 ————	water	9
		145

856. *Native Phosphate of Copper* has been found near Cologne. It is of a green colour, and forms small rhomboidal crystals.

857. *Carbonate of Copper*, artificially prepared, by adding carbonate of potassa to sulphate of copper and drying the precipitate, is a green compound, insoluble in water, consisting, according to Mr. R. Phillips, of 80 peroxide + 22 carbonic acid + 9 water. It is, therefore, a *subpercarbonate.* Copper, exposed to damp air, becomes incrusted with this compound. Exposed to heat, it loses water and carbonic acid, and leaves the peroxide. In order to heighten the green tint for which this compound is esteemed as a pigment, it should be repeatedly washed with boiling water.

858. There is a fine blue cupreous preparation, called *Refiners' Verditer*, principally made by silver refiners. It consists, according to Mr. R. Phillips, of 3 proportionals of oxide, 4 of carbonic acid, and 2 of water. (*Quarterly Journal of Science and Arts*, Vol. iv. p. 277.) There is a very inferior pigment, also called Verditer, which is a mixture of subsulphate of copper and chalk.

According to Pelletier, a good verditer may be obtained as follows: add a sufficient quantity of lime to nitrate of copper to throw down the hydrated oxide; it gives a greenish precipitate that is to be washed and nearly dried upon a strainer; then incorporate with it from 8 to 10 *per cent.* of fresh lime, which will give it a blue colour, and dry it carefully.

859. According to Mr. Chenevix, the alcaline carbonates dissolve a portion of the peroxide of copper, and form triple salts.

860. *Native Carbonate of Copper* is found of a green and blue colour. The former, or *Malachite*, is found in various forms, but never regularly crystallized, the octoëdral variety being a pseudo-crystal derived from the decomposition of the red oxide. This mineral occurs in the greatest beauty in the Uralian mountains of Siberia; it is rarely found in Cornwall. It is of various shades of green, and often cut into small slabs, or used as beads and broach stones. The pulverulent variety has been termed *chrysocolla* and *mountain green.*

The blue carbonate is found in great perfection at Chessy near Lyons; also in Bohemia, Saxony, *&c.* It occurs chrystallized in rhomboids and imperfect octoëdra; it also is found in small globular masses; massive; and earthy. The earthy variety is sometimes called *copper azure* or *mountain blue.*

The *Dioptase* or *Emerald Copper* is a very rare mineral, hitherto found only in Siberia, associated with malachite. It consists, according to Lowitz, of oxide of copper, silica, and water.

861. *Borate of Copper.*—Solution of borax, poured into sulphate of copper, produces a bulky pale green precipitate of borate of copper.

862. *Ferrocyanate of Copper* is a brown compound, obtained by adding ferrocyanate of potassa to a dilute solution of sulphate or nitrate of copper. Mr. Hatchett has recommended this substance as a brown pigment.

863. Many of the alloys of copper are important. With gold it forms a fine yellow ductile compound, used for coin and ornamental work. Sterling or standard gold consists of 11 gold + 1 copper. The specific gravity of this alloy is 17.157. With silver it forms a white compound, used for plate and coin. Lead and copper require a high red heat for union; the alloy is grey and brittle.—See *Gold* and *Silver.*

Of the alloys of copper with the preceding metals the most important are brass and bell-metal. It forms white compounds with potassium and sodium; a reddish alloy with manganese; and a grey one with iron.

864. *Brass* is an alloy of copper and zinc. The metals are usually united by mixing granulated copper with calamine (782) and charcoal: the mixture is exposed to heat sufficient to reduce the calamine and melt the alloy, which is then cast into plates. The relative proportions of the two metals vary in the different kinds of brass; there is usually from 12 to 18 *per cent.* of zinc. Brass is very malleable and ductile when cold; and its colour and little liability to rust recommend it in preference to copper for many purposes of the arts. According to M. Sage, a very beautiful brass may be made by mixing 50 grains of oxide of copper, 100 of calamine, 400 of black flux, and 30 of charcoal powder; melt these in a crucible till the blue flame is no longer seen round the cover; and, when cold, a button of brass is found at the bottom, of a golden colour, and weighing one-sixth more than the pure copper obtained from the above quantity of oxide.

865. The analysis of brass may be performed by solution in nitric acid; add considerable excess of solution of potassa and boil, which will dissolve the oxide of zinc and leave that of copper; wash the latter, and dry and heat it to redness; 125 parts indicate 100 of copper. The zinc in the filtered alcaline solution may be precipitated by carbonate of soda, having previously added a small excess of muriatic acid; wash this precipitate, dry it, and expose it to a red heat; it is then oxide of zinc, 123 parts of which indicate 100 of metal.

866. *Tutenag* is said to be an alloy of copper, zinc, and a little iron; and *Tombac*, *Dutch gold*, *Similor*, *Prince Rupert's metal*, and *Pinchbeck*, are alloys containing more copper than exists in brass, and consequently made by fusing various proportions of copper with brass. According to Wiegleb, *Manheim gold* consists of 3 parts of copper and 1 of zinc. A little tin is sometimes added, which, though it may improve the colour, impairs the malleability of the alloy.

867. *Speculum metal* is an alloy of copper and tin, with a little arsenic; about 6 copper, 2 tin, 1 arsenic. On this subject the reader is referred to Mr. Edwards's experiments.—NICHOLSON's *Journal*, 4to. iii.

868. *Bell metal* and *bronze* are alloys of copper and tin; they are harder and more fusible, but less malleable than copper; the former consists of 3 parts of copper and 1 of tin; the latter of from 8 to 12 of tin with 100 of copper. A little zinc is added to small shrill bells.

868*. The analysis of alloys of tin and copper may be performed by digestion in nitric acid, which dissolves the copper and converts the tin into insoluble peroxide, which, when washed and dried, consists of 100 tin + 27 oxygen. The cupreous solution may be decomposed by potassa, and the pure peroxide of copper indicates the quantity of that metal, as in the analysis of brass. (865.)

869. Vessels of copper used for culinary purposes are usually coated with tin, to prevent the food being contaminated with copper. *Their interior surface is first cleaned, then rubbed over with sal-ammoniac. The vessel is then heated, a little pitch spread over the surface, and a bit of tin rubbed over it, which instantly unites with and* covers the copper.

869*. The cupreous salts are nearly all soluble in water, and of a blue or green colour. Ammonia produces a compound of a very deep blue, when added in excess to these solutions; hydrosulphuret of ammonia forms a black precipitate; and a plate of iron plunged into a liquid salt of copper precipitates metallic copper.

Ferrocyanate of potassa is also an excellent test of the presence of copper; it produces a brown cloud in solutions containing the peroxide.

SECTION XIV. *Lead*.

To obtain pure lead.

870. THE natural compounds of this metal are very numerous. The most important is the sulphuret, from which the pure metal is chiefly procured. Lead is also found combined with carbonic, sulphuric, phosphoric, arsenic, molybdic, and chromic acids, and with oxygen and chlorine. To obtain lead perfectly pure, it may be dissolved in nitric acid; the solution evaporated to dryness; the dry mass re-dissolved in water and crystallized; these crystals heated strongly with charcoal afford the metal quite pure.

Characters of lead.

871. Lead appears to have been known in the earliest ages of the world. Its colour is bluish white. It melts at 600°, and by the united action of heat and air is readily converted into an oxide. Its specific gravity is 11.4. At common temperatures it undergoes little

change by mere exposure to air, but it is slowly corroded by the joint agency of air and water. Exposed upon ignited charcoal to a current of oxygen gas, it burns with a blue flame, throwing off dense yellow fumes of oxide. The alchymists gave this metal the name of *Saturn.*

872. *Oxides of Lead.*—There are three oxides of lead. The *protoxide* is the basis of the salts; it may be obtained pure by heating the nitrate of lead to redness in a vessel with a small orifice, till the whole of the acid is expelled. It is insipid and insoluble in water, of a pale yellow colour, and, when fused, crystallizes on cooling in irregular scales. It is volatile at a bright red heat. It is very soluble in solutions of potassa and soda; and when in fusion, it readily dissolves several of the earthy bodies, and of the common metallic oxides; hence the use of lead in *cupellation.* (885). If it be considered as a protoxide, consisting of one proportional of lead and one of oxygen, then the number 104 (deduced from the mean of the best analyses) will represent lead, and it will consist of 104 L. + 8 oxygen. This oxide is known in commerce under the name of *massicot;* or when vitrified, as obtained by calcining lead upon a large scale, it is called *litharge.*

When melted lead is exposed for a time to the air, it becomes incrusted with a grey pellicle, which, on removal, is succeeded by another, and so on until the whole is converted into a greenish grey powder, consisting of a mixture of the protoxide with metallic lead.

873. If the protoxide be exposed to heat and oxygen, it gradually acquires a bright red colour, and is known under the name of *minium* or *deutoxide* of lead. This oxide, when exposed to nitric acid, is resolved into protoxide, which is dissolved, and into *peroxide,* which is an insoluble brown substance, consisting of 104 L. + 16 oxygen. When peroxide of lead is heated it gives out half its oxygen and becomes yellow protoxide.

Minium affords, on analysis 104, L. + 12 oxygen, and may, therefore. be regarded as a definite compound of the protoxide and peroxide.

The minium or *red lead* of commerce generally contains a proportion of protoxide and of sulphate, with traces of chloride of lead and silica. To succeed in obtaining it of a fine red tint, it requires to be manufactured in quantities, and with several precautions. The method employed in Derbyshire is described in WATSON's *Chemical Essays,* Vol. iii. p. 338.

874. A substance supposed to be *native minium,* has been found in some of the Saxon and French lead mines, also in Yorkshire.

875. *Lead and Chlorine.*—*Chloride of Lead.* When laminated lead is heated in chlorine, the gas is absorbed, and a chloride of lead results, composed of 104 L. + 36 C. (J. DAVY, *Phil. Trans.,* 1812.) The same substance is obtained by adding muriatic acid to nitrate of lead; it is white and fusible, and on cooling forms a hornlike substance (*plumbum corneum.*) It volatilizes at a high temperature. It dissolves in 22 parts of water at 60°; is more soluble in boiling water, separating, as its solution cools, in small acicular crystals, unchanged by exposure to air, and of a sweetish taste. It dissolves in dilute nitric acid.

876. This substance is sometimes prepared by acting upon a solution of common salt by litharge; solution of soda and chloride of lead are formed; the insoluble residue when fused is known under the name of *patent yellow;* it appears to be a compound of oxide and of chloride of lead, for when treated by nitric acid, it forms nitrate of lead, and a portion of chloride separates.

877. *Native Chloride of Lead* has been found in Derbyshire and in Bavaria, crystallized in quadrangular prisms of a greenish yellow colour.

878. *Chlorate of Lead* is obtained by digesting the protoxide in chloric acid; it separates by slow evaporation, in white crystalline flakes of a very sweet taste. When heated it gives out oxygen and becomes a chloride.

879. *Iodide of Lead*, formed by heating leaf-lead with iodine, is a yellow insoluble compound. It is also formed by adding hydriodic acid or hydriodate of potassa to solution of nitrate of lead. It consists of

Iodine	125
Lead	104
	229

880. An insoluble *Iodate of Lead* is thrown down on adding iodate of potassa to any of the soluble salts of lead.

881. *Nitrate of Lead* is obtained by dissolving the metal, not in excess, in dilute nitric acid, and evaporation. The salt crystallizes in tetraëdra and octoëdra, which are white translucent, and of a styptic taste. It is soluble in 8 parts of water at 212°. It consists of 112 oxide of lead + 54 nitric acid. The alcalis throw down protoxide of lead from the solution of this salt.

882. *Subnitrate of Lead* may be formed by boiling a mixture of equal weights of nitrate and protoxide of lead in water, filtering while hot, and setting it by to crystallize; it forms pearly crystals, of a sweet astringent taste. (Chevreuil, *Annales de Chimie*, lxxxii.) It consists of two proportionals oxide = 224, + one proportional nitric acid = 54.

883. Chevreuil and Berzelius have described three *nitrites* of lead, but their composition appears doubtful. (*Ann. de Chim.*, lxxxiii. and lxxxviii.) A detailed account of them is given by Dr. Thomson.—*System*, ii. 578.

884. *Sulphuret of Lead* may be formed artificially by fusion. Its lustre and colour much resemble pure lead, but it is brittle: it consists of 104 lead + 16 sulphur.

Litharge.

885. *Native Sulphuret of Lead*, or *Galena*, is the principal source of the vast commercial demands of the metal. It occurs massive and crystallized, chiefly in the older secondary rocks. Its primitive form is the cube, of which there are several modifications, and among them the octoëdron. It often contains traces of silver, and sometimes in such quantity as to render it worth separating, which is effected by exposing the roasted sulphuret to the action of heat and air in shallow earthen dishes; the lead becomes oxidized and converted into litharge, while the silver is left pure, in consequence of its power of resisting the influence of heat and air. This process is called *cupellation*. The litharge is afterwards reduced by fusion with charcoal.

Reduction of the ore.

The reduction of galena upon a large scale is a sufficiently simple process. The picked ore, after having been broken and washed, is roasted in a reverberatory fire, the temperature being such as to soften but not fuse it. During this operation it is raked till the fumes of sulphur are dissipated, when it is brought into perfect fusion; the lead sinks to the bottom, and is run out into oblong moulds called *pigs*; the scoriæ are again melted, and furnish a portion of less pure metal.

The mines of Great Britain afford an annual produce of about 48000 tons of smelted lead, of which nearly the whole is obtained from the sulphuret.

Slickensides. There is a peculiar variety of galena, called in Derbyshire *slickensides;* and which, when touched by the miner's pick, often splits asunder with a kind of explosion.

886. *Hyposulphite of Lead* is precipitated in the form of a white powder, nearly insoluble in water, by adding solution of nitrate of lead to hyposulphite of potassa. It is composed, according to Herschel, of 70.30 protoxide of lead + 29.70 hyposulphurous acid. These numbers correspond to 1 proportional of oxide of lead = 112 + 2 proportionals of hyposulphurous acid = 48.

887. *Sulphite of Lead* may be obtained by digesting yellow oxide of lead in sulphurous acid; or by adding sulphurous acid or sulphite of potassa to nitrate of lead. It is white, insoluble, and tasteless, and consists of one proportional of each of its components; namely, 32 sulphurous acid + 112 oxide of lead. When heated it loses sulphurous acid.

888. *Sulphate of Lead.* When metallic lead is boiled in concentrated sulphuric acid, sulphurous acid is evolved, and a white sulphate of lead is formed. It is so nearly insoluble, that it may be formed by adding dilute sulphuric acid, or an alcaline sulphate, to a solution of nitrate of lead. Dr. Thomson found, that after having been dried at a temperature of 400°, it might be heated to redness in a platinum crucible without losing weight. Heated on charcoal by the blowpipe, it is decomposed and reduced. It consists of one proportional of sulphuric acid = 40, and one proportional of oxide of lead = 112; and its representative number is therefore 152. Sulphate of lead is insoluble in alcohol and in nitric acid: it is sparingly soluble in dilute sulphuric acid, and separates from it in small prismatic crystals.

889. *Native Sulphate of Lead* is found in Anglesea, and in Scotland, crystallized in prisms and in octoëdra.

890. *Hydrosulphuretted Oxide of Lead* is of a deep brown colour, and is produced by adding sulphuretted hydrogen, or hydrosulphuret of ammonia, to any solution of lead; hence the use of those compounds as tests of the presence of lead.

891. *Phosphuret of Lead* may be formed by dropping phosphorus into melted lead. It is of the colour of lead, and soon tarnishes.

892. *Hypophosphite of Lead* has not been examined.

893. *Phosphite of Lead* was prepared by Berzelius by mixing muriate of lead with phosphite of ammonia. It is white, tasteless, and insoluble, and appears to consist of 1 proportional of oxide of lead = 112 + 1 proportional of phosphorous acid = 20.

894. *Phosphate of Lead* is formed by mixing solutions of nitrate of lead and phosphate of soda, or phosphoric acid. It is yellowish white; insoluble in water; soluble in fixed alcaline solutions, and in nitric acid. It is decomposed by sulphuric acid, and by hot muriatic acid. It fuses before the blowpipe, and crystallizes on cooling. It consists of 112 oxide of lead + 28 phosphoric acid = 140.

895. Berzelius has described a *subphosphate*, a *superphosphate*, and a *nitrophosphate of lead.*—*Annales de Chim. et Phys.*, ii.

896. *Native Phosphate of Lead* has been found in the mines of Cumberland, Durham, Yorkshire, and of Wanlock Head, in Scotland.

Its colour is various shades of green, yellow, and brown. Its primitive form is a rhomboid, but it usually occurs in six-sided prisms. It is semi-transparent and brittle.

897. *Carbonate of Lead.*—When an alcaline carbonate is added to nitrate of lead, a white precipitate of carbonate of lead falls: it is tasteless, insoluble in water, but soluble in fixed alcaline solutions. It is employed as a white paint, under the name of *white lead* or *ceruse*, and is usually prepared by exposing sheet lead to the action of the vapour of vinegar. The process is described in AIKIN's *Dictionary*, (*Art.* LEAD.) It consists of 112 oxide of lead + 22 carbonic acid = 134 carbonate of lead.

898. *Native Carbonate of Lead* is one of the most beautiful of the metallic ores: it occurs crystallized and fibrous, the former transparent, the latter generally opaque. It is soft and brittle, and occasionally tinged green with carbonate of copper, or grey by sulphuret of lead. The octoëdron is its primitive form: it also occurs prismatic and tabular. It has been found in Cumberland and Durham, and the acicular variety of great beauty in Cornwall.

899. Ferrocyanate of potassa produces a white precipitate when added to the soluble salts of lead.

900. *Borate of Lead* is precipitated in the form of a white powder, when borate of soda is mixed with nitrate of lead.

Characters of the salts of lead.

901. The soluble salts of lead have a sweetish austere taste, and are *characterized by the white precipitate produced by ferrocyanate of potassa, the deep brown by hydrosulphuret of ammonia, and the yellow by hydriodate of potassa.*

The salts insoluble in water are dissolved by soda and potassa, and by nitric acid, when the metal is rendered manifest by sulphuretted hydrogen and other tests. Heated by the blowpipe upon charcoal they afford a button of metal.

902. *The Alloys of Lead* with the preceding metals are not important, if we except that which it forms with tin. Common *pewter* consists of about 80 parts of tin and 20 of lead. Equal parts of lead and tin constitute *plumbers' solder;* and what is termed *pot-metal* is an alloy of lead and copper.

903. In analyzing these alloys, 100 grains in filings may be boiled to dryness in two ounces of nitric acid, water poured upon the residue, and filtered; the peroxide of tin remains in the filter, and the nitrate of lead, which passes through in solution, may be converted into sulphate by adding sulphate of soda. 152 grains of sulphate of lead dried at a red heat, indicate 104 of metal; and 75 grains of washed peroxide of tin are equivalent to 59 grains of metallic tin.

904. With potassium lead forms a brittle and very fusible alloy; with sodium the compound is equally brittle but less fusible. When exposed to air these alloys suffer decomposition in consequence of the oxidizement of the alcaline bases. The alloy of Lead and Manganese has not been examined. When lead is fused with iron two alloys are obtained; that at the bottom of the crucible consisting of lead with a little iron; while the superficial portion is iron with a little lead (GUYTON MORVEAU, *Ann. de Chim.*, lvii.) With zinc, lead forms a hard ductile alloy.

SECTION XV. *Antimony.*

905. THIS metal is found *native* in Sweden, in France, and in the Hartz; but its principal ore is the *sulphuret* which is found massive and crystallized, and of which there are several varieties. The most common is the *radiated*, which is of a grey colour, brittle, and frequently crystallized in four and six-sided prisms. This ore may be decomposed, and the pure metal obtained from it, by the following process: Mix three parts of the powdered sulphuret with two of crude tartar, and throw the mixture by spoonfuls into a red-hot crucible; then heat the mass to redness, and a button will be found at the bottom of the crucible, which is the metal as it commonly occurs in commerce, and is nearly pure. Reduce this button to fine powder, and dissolve it in nitro-muriatic acid; pour this solution into water, which will occasion the precipitation of a white powder, which is to be washed and mixed with twice its weight of tartar and exposed to a dull red heat in a crucible. The button now obtained is pure antimony. Reduction of ore.

906. Antimony is of a silvery white colour, brittle, and crystalline in its ordinary texture. It fuses at about 800°, and is volatile at a high heat. Its specific gravity is 6.712. (HATCHETT, *Phil. Trans.*, 1803.) Placed upon ignited charcoal, under a current of oxygen gas, antimony burns with great brilliancy, throwing off its oxide in the form of a dense yellow smoke.

907. *Antimony and Oxygen.*—These bodies form two well-defined compounds, the history of which is of great importance to the pharmaceutical chemist.

The *Protoxide of Antimony* is thus obtained: To 200 parts of sulphuric acid add 50 parts of powdered metallic antimony. Boil the mixture to dryness, wash the dry mass, first in water, and then with a weak solution of carbonate of potassa; a white powder remains, which when thoroughly washed with hot water, is *Protoxide of Antimony*. It may also be procured by dissolving antimony in muriatic acid, pouring the solution into water, and washing the white precipitate with weak solution of potassa.

908. This oxide may also be obtained by adding ammonia to solution of tartrate of antimony and potassa, heating the mixture and washing the precipitate in large quantities of boiling water. It is thus procured in the form of a heavy white powder. This process is directed in the *Pharmacopœia*.

This protoxide exists in all the active antimonial preparations; in emetic tartar, kermes, glass of antimony golden sulphuret, *&c.* It is fusible and volatile at a red heat: decomposed by sulphur and charcoal and when acted on by nitric acid, is converted into peroxide. If heated with chlorate of potassa it deflagrates and also becomes peroxidized; it is very soluble in muriatic acid, and readily forms emetic tartar when boiled in solution of tartrate of potassa.

When metallic antimony in fusion is exposed to a bright red heat, it is converted into an oxide which appears to be the protoxide, and which condenses in long and delicate needles when sublimed. It was formely called *argentine flowers of antimony.*

909. *Peroxide of Antimony* is procured by acting for a considerable

time upon the powdered metal, by excess of hot nitric acid, and exposing the product to a red heat. The *diaphoretic antimony* and *Bezoar mineral* of old *Pharmacopœiæ* consisted of this oxide, which compared with the protoxide is nearly inert.

910. Peroxide of antimony is also formed by exposing the metal or the protoxide mixed with five or six parts of nitre to a red heat, in a porcelain crucible, and washing the residue with hot water. It is yellowish white, but becomes buff-coloured when heated, and returns to its former tint on cooling. It neither fuses nor volatilizes at a bright red heat, but when exposed to the flame of a spirit-lamp urged by a blow-pipe, it passes off slowly in white fumes, being partially reduced by the hydrogen of the flame.

911. Berzelius (*Ann. de Chim.*, lxxxvi. 225), has described four oxides of antimony; but it is probable that the first and the fourth are not distinct compounds: they are said to be constituted as follows:

1	Suboxide consisting of	100 antimony	+	4.65 oxygen.
2	Oxidule	100	+	18.60 . . . . . .
3	White oxide	100	+	27.90 . . . . . .
4	Yellow oxide	100	+	37.20 . . . . . .

The two last oxides are called by Berzelius, *stibious* and *stibic* acids, or *antimonious* and *antimonic* acids.

The second and fourth are probably the oxides described in paragraphs 908 and 909, but their composition is by no means satisfactorily ascertained.

912. *Native Oxide of Antimony* is occasionally found incrusting the native metal and the sulphuret.

913. I have found by experiment that the oxygen in the protoxide (908) is to that in the peroxide (909) as 1 to 2; and if we consider these as the second and fourth oxide described by Berzelius, we obtain the number 40 as the representative of antimony. Dr. John Davy's researches on the composition of the chlorides, (*Phil. Trans.*, 1812,) give the number 42.5 as the representative of antimony; and this nearly agrees with my own experiments upon the composition of the protoxide, (obtained by precipitation from emetic tartar), which give 45, and which I shall therefore adopt.

The protoxide of antimony will then consist of

Antimony 48 + Oxygen 8 = 56*.

And the peroxide will be composed of

Antimony 48 + Oxygen 16 = 64.

914. The acid properties of peroxide of antimony were long since remarked by Thenard, (*Ann. de Chim.*, xxxviii. and xli.) and the subject has lately been investigated by Berzelius, who obtained it by exposing a mixture of one part of powdered antimony and six of nitre to

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* 45 is merely altered to 48 in order to be proportional to 8 instead of 7.5 oxygen. The great discrepancy in the results of different Chemists makes it improper to offer any number confidently. Brand gives his own the preference, although it does not agree with the 42.5 of Dr. D. any better than the 40 stated in his text.

a red heat in a silver crucible for an hour. After washing off the soluble matters by cold water, and digesting the white powder which remains in muriatic acid, washing and drying it at a red heat, it is pure *antimonic acid*, and consists of antimony 100, oxygen 37.2.

915. *Antimoniate of Ammonia* is formed by digesting the acid in ammonia. On evaporation a *superantimoniate of ammonia* is obtained in the form of a white powder.

916. *Antimoniate of Potassa* is contained in the white powder obtained by igniting nitre and antimony. (919). It dissolves in hot water, and this solution produces precipitates of insoluble antimoniates in several other metallic solutions.

Our knowledge of the composition and properties of the oxides of antimony, and of most of their combinations, is still extremely imperfect, and the whole subject requires further investigation before the anomalies that now present themselves can be cleared up.

917. *Antimony and Chlorine* combine in one proportion only to produce the *chloride of antimony*. The powdered metal takes fire when thrown into the gas, and a compound, at first liquid, but afterwards concreting, is formed. It may also be produced by the distillation of one part of powdered antimony with two and a half of bi-chloride of mercury; or by dissolving the protoxide of antimony in muriatic acid, and evaporating to dryness. It consists of 48 A. + 36 C. The pure chloride is a soft solid at common temperatures, but becomes *liquid* by a gentle heat, and crystallizes as it cools. It is the *butter of antimony* of old writers. It deliquesces by exposure to air; and is a powerful caustic. When water is added to the chloride of antimony, a mutual decomposition ensues, and hydrated protoxide of antimony, formerly called *Algarotti's powder*, or *mercurius vitæ*, and muriatic acid result.

918. *Chlorate of Antimony* has not been examined.

919. *Iodide of Antimony* is of a dark red colour; acted upon by water, it produces hydriodic acid and oxide of antimony.

920. *Iodate of Antimony* is unknown.

921. Nitric acid acts powerfully on metallic antimony, and if mixed with it in fine powder, will sometimes cause its inflammation. The metal becomes peroxidized, and scarcely an appretiable portion is retained in solution. As in some other cases of the vehement decomposition of nitric acid, ammonia is produced, (287) which may be rendered sensible by pouring potassa on the white magma that results.

Protoxide of antimony, digested in dilute nitric acid, produces a difficultly soluble salt, which separates in white scaly crystals, and which appears to be a *nitrate of antimony*, but I have not particularly examined it.

922. Nitro-muriatic acid readily dissolves antimony, and forms an orange-coloured solution, which is decomposed by the addition of water. Iron or zinc immersed into this solution throws down a black powder, which, according to Thenard, is pyrophoric.

923. *Sulphuret of Antimony* is easily formed by fusing the metal with sulphur. It consists of 48 A. + 16 S. Its colour is dark grey and metallic. Its specific gravity 4.36. It closely resembles the native sulphuret (905.)

924. When the native sulphuret is exposed under a muffle to a dull red heat, it gradually loses sulphur and absorbs oxygen, being converted into a grey powder, which consists of a mixture of protoxide of an-

timony and sulphuret. If the heat be increased, this fuses into a transparent substance of a yellow or brown colour, formerly called *glass of antimony*. Its composition is variable; it generally contains about 85 *per cent.* of protoxide and 15 of sulphuret. In that which is imported for pharmaceutical purposes, from Germany and Holland, there is usually a portion of siliceous earth, and it is sometimes adulterated with oxide of lead. This fraud is easily detected by digesting the finely powdered glass in hot nitric acid, diluting the solution and filtering. The filtered liquor gives a white precipitate on the addition of sulphate of soda if lead were present. Glass of antimony.

During the formation of glass of antimony, if the heat be raised too high the greater part of the protoxide sublimes in slender crystalline needles; while another portion, if air be not excluded, passes into the state of peroxide, and undergoes no change at a very high temperature.

Compounds of the protoxide with larger quantities of the sulphuret have been termed *saffron of antimony* or *crocus metallorum*, and *liver of antimony*.

925. Neither the *Hyposulphite* nor the *Sulphite* of antimony are known.

926. *Sulphate of Antimony.*—When sulphuric acid is boiled upon finely-powdered antimony, the metal is oxidized, and an acid *sulphate* and a *subsulphate* of *antimony* are the results. In both these salts the metal is in a state of protoxide. (907.)

927. *Hydrosulphuretted Oxide of Antimony.*—This compound has long been known under the name of *kermes mineral;* it is commonly prepared as follows: Equal parts of sulphuret of antimony and common potash are fused together; the resulting mass is finely powdered and boiled in ten times its weight of water. The liquor is filtered while hot; and, during cooling, it deposits *kermes.* The mother liquor of kermes deposits a copious yellowish red precipitate upon the addition of dilute sulphuric acid, which, when washed and dried, is known under the name of *golden sulphur of antimony.* In the *London Pharmacopœia* it is called *antimonii sulphuretum præcipitatum.*

In forming these compounds, the following changes seem to have taken place. The sulphuret of antimony and potassa act upon the water, a portion of which is decomposed; hydrogen is transferred to the alcaline sulphuret, to form hydrosulphuret of potassa; hydrogen and oxygen unite to the sulphuret of antimony, producing a hydrosulphuretted oxide of that metal (*kermes*), which remains dissolved in the hot alcaline hydrosulphuret, and of which one portion is precipitated as that solution cools. When dilute sulphuric acid is added, the hydrosulphuret of potassa is decomposed, sulphate of potassa is formed, and sulphur and sulphuretted hydrogen are liberated; the sulphur falls in combination with the *kermes*, producing the *golden sulphur*, or sulphuretted hydrosulphuret.

928. *Phosphuret of Antimony* is formed by heating together equal parts of oxide of antimony, phosphoric acid, and charcoal. It is white and brittle.

929. Nothing is known respecting either the *Hypophosphite* or the *Phosphite* of antimony.

930. *Phosphate of Antimony* has not been formed: in the *London Pharmacopœia* there is a preparation called *pulvis antimonialis*, formed by heating one part of sulphuret of antimony with two of hartshorn

shavings. The action of heat upon the sulphuret has already been described. (924.) Its effect upon the hartshorn shavings is to destroy the animal matter, leaving little else than phosphate of lime. So that the *pulvis antimonialis* consists essentially of protoxide of antimony, mixed with phosphate of lime. This preparation is usually considered analogous to, if not identical with, *James's Powder*, which, according to Dr. Pearson's analysis (*Phil. Trans.*, 1791), consists of 43 phosphate of lime, and 57 oxide of antimony.

Mode of preparing antimonial powder.

931. In examining Antimonial Powder from various sources, prepared according to the direction of the *Pharmacopœia*, I have found it of very variable composition: sometimes it contains peroxide of antimony only; sometimes there is a proportion of protoxide, and in some few cases the powder has consisted chiefly of bone-earth. These differences are referable to the mode of preparing it, but in almost every case, a very large proportion of the protoxide is lost during the process, and I have found it a matter of great difficulty so to conduct it as to obtain, upon the large scale, an uniform product. For medical use I should consider emetic tartar as the only certain and necessary preparation of antimony; if, however, a compound of the nature of the Antimonial Powder be requisite, one of the best modes of preparing it would be to dissolve certain proportions of protoxide of antimony and phosphate of lime in muriatic acid, precipitate by ammonia, and edulcorate with a large quantity of water. Mr. Chenevix advises for this purpose equal parts of the oxide and phosphate, but such proportion of antimony is too great: I have made an useful Antimonial Powder by dissolving 200 grains of bone-earth and 100 of protoxide of antimony in a measured ounce and a half of muriatic acid, and pouring the solution into a weak solution of ammonia; the precipitate, when washed, dried, and reduced to a fine powder, weighed 280 grains.

932. The following method furnishes, in the dry way, a tolerably uniform Antimonial Powder: Burn two pounds of hartshorn to a cinder, reduce it to powder, and heat it to a dull redness in an iron pot: then gradually stir into it one pound of powdered sulphuret of antimony, added in successive portions, and continue the same heat as long as fumes arise; when these cease the mixture will have a dirty grey colour, and during the operation small crystals of protoxide of antimony will be seen to collect upon its surface when a portion is taken out in an iron spoon. In this grey state it should be put into a crucible and heated to intense redness; a phosphorescent light of a greenish tint is soon perceived, and when this ceases the crucible may be removed from the fire, and its contents when cold reduced to a fine powder, which should be perfectly white.

933. Neither *carbonate*, *hydrocyanate*, nor *borate* of antimony are known to exist.

934. The solutions of antimony afford orange-coloured precipitates with sulphuretted hydrogen, and those which are acid are precipitated when largely diluted with water.

935. Antimony forms brittle alloys with the malleable metals. When gold was alloyed with $\frac{1}{1920}$ its weight of antimony, the compound was perfectly brittle; and even the fumes of antimony in the vicinity of melted gold are sufficient to destroy its ductility. (HATCHETT, *Phil. Trans.*, 1803.) With potassium and sodium it forms white brittle compounds, destructible by the action of air and water.

Its alloys with manganese and with zinc have not been examined.

Alloyed with lead in the proportion of 1 to 16, and a small addition of copper, antimony forms the alloy used for *printers' types*. With lead only, a white and rather brittle compound is formed, used for the plates upon which music is engraved. With iron it forms a hard whitish alloy formerly called *martial regulus*, which may be obtained by fusing two parts of sulphuret of antimony with one of iron filings; a scoria consisting chiefly of sulphuret of iron is formed, and the fused alloy beneath usually presents a stellated appearance in consequence of its crystallization. This star was much admired by the alchymists, who considered it a mysterious guide to transmutation. With tin antimony constitutes a kind of *pewter*, a term however which has also been applied to some other alloys, especially that of lead and tin. (902.) The finest pewter consists of about 12 parts of tin and 1 of antimony, with a small addition of copper. A good white metal, used for teapots, is composed of 100 tin, 8 antimony, 2 bismuth, and 2 copper. Alloys.

936. The analysis of an alloy of tin, lead, copper, and antimony, may be thus performed: Introduce 100 grains into a matrass with a wide mouth, and pour upon it one ounce of water and two of nitric acid; digest and evaporate to dryness. The dry mass will consist of the nitrates of lead and copper, which are soluble, and may be taken up by two ounces of hot water, and of the peroxides of tin and antimony, which are insoluble, and remain upon the filter.

To the solution of the nitrates add sulphate of soda, which throws down sulphate of lead, and which is to be collected in a filter, washed, dried at a red heat, and weighed. (888.) The filtered liquor may be evaporated to about two ounces in bulk, and having rendered it slightly acid by dilute sulphuric acid, immerse in it a plate of iron, which will throw down metallic copper, to be purified if requisite (820), dried, and weighed.

The separation of the peroxides of tin and antimony is attended with many difficulties; it may be imperfectly effected by solution in nitromuriatic acid, and subsequent dilution with a large quantity of water, which throws down the antimonial oxide, not however pure, but with a portion of peroxide of tin: the latter, retaining a little peroxide of antimony, may be procured by evaporation and exposure of the residue to a dull red heat in a porcelain cup.

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Section XVI. *Bismuth.*

937. This metal is found native; combined with oxygen; and with arsenic and sulphur.

Native Bismuth occurs crystallized in octoëdra and cubes, and generally contains arsenic and sometimes cobalt. It has been found in Cornwall, and in Germany, France, and Sweden.

938. The metal may be obtained pure, by dissolving the bismuth of commerce in nitric acid; water is added to the nitric solution, which separates oxide of bismuth. This oxide is easily reduced in the usual way.

Bismuth is a brittle white metal, with a slight tint of red: its specific gravity is 9.822. (HATCHETT, *Phil. Trans.*, 1803.) It fuses at 476°, and always crystallizes on cooling.

939. When bismuth is exposed to heat and air it oxidizes, forming a fusible *white oxide.* If the heat be increased by directing a current of oxygen upon the metal, it burns with much brilliancy, and produces an abundant yellow smoke, which condenses in the form of a yellowish white sublimate. When in fusion this oxide acts upon other oxides much in the same way as oxide of lead. It consists of 72 bismuth + 8 oxygen. It occurs, though very rarely, *native:* it has been found in Cornwall and Saxony.

940. *Chloride of Bismuth*, is procured by heating the metal in the gas, or by evaporating the muriate to dryness and submitting the residue to distillation, when the chloride sublimes, and afterwards deliquesces into what was called *butter of bismuth.* (J. DAVY, *Phil. Trans.*, 1812.) It consists of 72 bismuth + 36 chlorine.

941. *Chlorate of Bismuth* has not been examined.

942. *Iodide of Bismuth*, obtained by heating iodine with the metal, is of an orange-colour, and insoluble in water. When hydriodic acid or hydriodate of potassa is added to nitrate of bismuth, a precipitate falls of a deep chocolate-brown colour, insoluble in water but soluble in liquid potassa.

943. *Iodate of Bismuth* is thrown down upon adding iodate of potassa to nitrate of bismuth.

944. *Nitrate of Bismuth.*—This salt crystallizes in small four-sided prisms, consisting of 80 oxide + 54 acid. It is made by dissolving the metal to saturation in two parts of nitric acid and one of water: the action is rapid, and nitric oxide is copiously evolved. Ammonia occasions a precipitate in nitrate of bismuth, which is re-dissolved by excess of the alcali. Potassa and soda also throw down the oxide, which is but sparingly soluble in those alcalis.

945. Nitrate of Bismuth is decomposed by water, and the oxide of bismuth is thrown down in the form of a fine white powder, called *magistery of bismuth*, *pearl white*, or *blanc de fard.* In this state it has been used in medicine as a tonic.—*Quarterly Journal*, viii. 295.

946. If characters be written on paper with nitrate of bismuth they are invisible when dry, but become white and legible on immersion in water, thus forming a *white sympathetic ink.* The same characters are rendered brown or black by solution of sulphuretted hydrogen.

947. *Sulphuret of Bismuth* is of a bluish colour and metallic lustre; it consists of 72 B. + 16 sulphur. (J. DAVY, *Phil. Trans.*, 1812.) The compound analyzed by Vauquelin appears to have been a *bi-sulphuret.*—*Annales du Museum*, Tom. xv.

948. *Native Sulphuret of Bismuth* has been found in Cornwall, Bohemia, Saxony, and Sweden. It occurs massive and acicular, its lustre is metallic, and its colour bluish grey. It is a very rare mineral.

949. Neither the *Sulphite* nor the *Hyposulphite of Bismuth* have been examined.

950. *Sulphate of Bismuth* consists of 80 oxide + 40 acid; it is a white compound, insoluble in, but decomposed by water, which converts it into a *subsulphate* and *supersulphate.*

951. *Hydrosulphuretted Oxide of Bismuth* is of a deep brown approaching to black. It is thrown down from nitrate of bismuth by sulphuretted hydrogen.

952. *Phosphuret of Bismuth* does not, according to Pelletier, exist; at least, it cannot be formed by the usual process.

953. Neither the *hypophosphite*, *phosphite*, *phosphate*, *carbonate*, *ferrocyanate*, nor *borate* of bismuth have been sufficiently examined.

954. Bismuth forms *alloys*, some of which are remarkable for their fusibility. With gold, platinum, and silver, it forms brittle compounds. A compound of eight parts of bismuth, five of lead, and three of tin, liquefies at 212° ; it is called Sir. I. Newton's *fusible metal*. The addition of one part of quicksilver renders it yet more fusible. Bismuth enters into the composition of *soft solders*. These alloys are mostly white, brittle, and easily oxydated.

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SECTION XVII. *Cobalt.*

955. THE native combinations of cobalt are the oxide, and compounds of the metal with iron, nickel, arsenic, and sulphur. It is also found combined with arsenic acid. In the white and grey cobalt ores, the metal is combined with iron, and with arsenic: Some of the varieties are crystallized in cubes, octoëdrons and dodecaëdrons. The red ore is an arseniate. The finest specimens are the produce of Saxony.

To obtain pure cobalt.

956. To obtain pure cobalt, the cobalt of commerce, in fine powder, may be calcined with four parts of nitre, and washed in hot water, by which arsenic is separated: then digest in dilute nitric acid, and immerse a plate of iron, which will separate the copper; filter and evaporate to dryness; digest the dry mass in liquid ammonia and filter; expel the excess of ammonia from the filtered liquor by heat, taking care not to produce a precipitate, and then add solution of potassa, which throws down oxide of nickel; filter immediately, and boil, which will occasion the separation of oxide of cobalt, and which, ignited with charcoal, furnishes the pure metal. In this process the first calcination with nitre often requires two or three repetitions in order to get rid of the whole of the arsenic, which adheres to cobalt with much obstinacy.

957. Cobalt is of a reddish grey colour, brittle, and difficultly fusible. Its specific gravity is 7.7. It is magnetic.

958. *Cobalt and Oxygen* unite in two proportions. The *Protoxide* is formed by adding potassa to the nitrate, and drying the precipitate; it appears very dark blue or nearly black. By exposure to heat and air it absorbs an additional portion of oxygen, and is thus converted into black *peroxide*. The protoxide, when recently precipitated and moist, is *blue*; and, if left in contact of water, becomes a *red hydrate*. The composition of the protoxide of cobalt, deduced from the analysis of the chloride (960) is 32.5 cobalt + 8 oxygen = 40.5; or 100 cobalt + 24.7 oxygen*.

This result is nearly the mean of those published by Proust, (*Annales de Chimie*, Vol. lx.) and Rothoff, (*Annals of Phil.* Vol. iii.) It appears from the experiments of the latter chemist, that the peroxide of cobalt contains 100 metal + 36.7 oxygen, which, in reference to the above deduction from the chloride, would lead us to consider it as containing one proportional of cobalt and one and a half of oxygen. All the salts of cobalt contain the protoxide.

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* Thomson in his last experiments (Ann. Ph. new series, p. 251) makes the atom of cobalt = 26. The number given above does not agree with a law which seems well established by all the foregoing substances, viz. that all numbers are *even integers* when hydrogen = 1.

959. Cobalt burns when heated in chlorine; and forms *chloride of cobalt*. When muriate of cobalt is evaporated to dryness, and the residuum heated to redness out of the contact of air, a substance of a blue colour and micaceous texture is obtained, which is a pure chloride of cobalt. It dissolves perfectly in water, forming a pink solution.

960. As the chloride of cobalt is easily formed, and as it is a perfectly definite compound, it offers an unexceptionable substance, from which, by analysis, to deduce the equivalent number of the metal. For this purpose 32 grains of the pure chloride were dissolved in water, and decomposed by solution of nitrate of silver: the precipitate of chloride of silver dried at a dull red heat, weighed 68 grains, which is the equivalent of 16.73 grains of chlorine; hence the 32 grains of chloride of cobalt are composed of 16.73 chlorine + 15.27 cobalt; and 16.73 : 15.27 : : 36 : 32.8 = the equivalent of cobalt. The chloride of cobalt, therefore, may be considered as composed of

1 proportional of cobalt . . . = 32.8
1 ——— chlorine . . = 36.0
———
68.8

961. *Chlorate of Cobalt* has not been examined.

962. *Muriate of Cobalt* is a deliquescent salt, of a blue green colour; it may be formed by digesting either oxide in muriatic acid; if the peroxide be used, chlorine is evolved, and it passes to the state of protoxide. When a little diluted, this solution becomes pink; the pale pink solution, when written with, is scarcely visible; but if gently heated, the writing appears in brilliant green, which soon vanishes as the paper cools, in consequence of the salt absorbing the aërial moisture. This solution has been termed *Hellot's sympathetic ink*.

963. *Iodide* and *Iodate of Cobalt* remain unexamined. No precipitate is produced in muriate of cobalt either by hydriodic acid or hydriodate of potassa.

964. With nitric acid the oxide of cobalt furnishes a red deliquescent *nitrate of cobalt.*

965. Ammonia digested upon recently precipitated protoxide of cobalt slowly dissolves it, and forms a pale pink solution, which becomes deeper coloured by exposure to air, in consequence of the metal passing to the state of peroxide. The ammoniacal solution of the peroxide forms acicular crystals of a beautiful pink colour.

966. *Sulphuret of Cobalt* is formed by heating the oxide with sulphur. It is yellowish white.

967. Neither the *Sulphite* nor the *Hyposulphite of Cobalt* have been examined.

968. *Sulphate of Cobalt* forms red rhombic crystals, soluble in 24 parts of water at 60°. It may be made by dissolving the newly precipitated protoxide in sulphuric acid diluted with its bulk of water. In

its crystallized state it consists of one proportional of oxide, one of acid, and seven of water; or

40.5	protoxide of cobalt
40.	sulphuric acid
63.	water
143.5*	

When dried at a temperature of 500°, the crystals fall into a blue powder, which in a bright red heat fuses and gives out sulphuric acid leaving a black oxide. The blue powder is the *anhydrous sulphate of cobalt*, perfectly soluble in water, and forming a pink solution; it is slightly deliquescent, and becomes lilac coloured by exposure to air.

969. Fifty grains of dry sulphate of cobalt dissolved in water, furnished a precipitate with muriate of baryta, amounting, when dried at a red heat, to 75 grains of sulphate of baryta, which is the equivalent of 25.5 grains of sulphuric acid: this method of analysis, therefore, shows that sulphate of cobalt consists very nearly of equal weights of sulphuric acid and protoxide of cobalt, and may be considered as verifying the analysis of the chloride. (960.)

970. Sulphate of cobalt forms triple compounds with potassa and with ammonia, which have not been examined. If it contain nickel, the crystals are of a greenish tinge, but pink when the cobalt is pure.

971. *Hydrosulphuretted Oxide of Cobalt* is precipitated from the muriate by hydrosulphuret of ammonia, of a black colour.

972. *Phosphuret of Cobalt* is a white brittle compound.

973. Nothing is known respecting the *Hypophosphite* and *Phosphite of Cobalt*.

974. *Phosphate of Cobalt* may be formed by double decomposition, as by adding phosphate of soda to muriate of cobalt; it is insoluble, of a lilac colour, and if mixed with eight parts of gelatinous alumina and heated, it produces a beautiful blue, which may sometimes be employed by painters as a substitute for ultramarine. (Thenard, Tom. ii. p. (Thomson.) 419.) The theoretical composition of phosphate of cobalt is 34 oxide + 28 acid = 62. (Thomson.)

975. *Carbonate of Cobalt* is formed by decomposing the nitrate, muriate, or sulphate of cobalt by carbonate of potassa, or soda; a reddish blue powder is precipitated.

976. Ferrocyanate of potassa forms a grass green precipitate in solutions of cobalt.

977. Solution of borax produces a pink precipitate in solution of muriate of cobalt, which is probably a *borate of cobalt*.

978. The salts of cobalt all contain the protoxide; they are decomposed by ammonia, which, if added in excess, re-dissolves the oxide: phosphoric, carbonic, arsenic, and oxalic acids, produce, by double decomposition, insoluble red or lilac precipitates in these solutions.

979. The alloys of cobalt are unimportant.

980. The chief use of cobalt is as a colouring material for porcelain, earthenware, and glass; it is principally imported from Germany in the state of *zaffre*, and *smalt* or *azure*.

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* If Thomson's number 26 (which seems preferable) the oxide will be 26 + 8 = 34, and the compound = 34 protox: + 40 sulphuric acid + 63 water = 137.

Zaffre is prepared by calcining the ores of cobalt, by which sulphur and arsenic are volatilized, and an impure oxide of cobalt remains, which is mixed with about twice its weight of finely-powdered flints.

Smalt and *azure blue* are made by fusing zaffre with glass; or by calcining a mixture of equal parts of roasted cobalt ore, common potash, and ground flints. In this way a blue glass is formed, which, while hot, is dropped into water, and afterwards reduced to a very fine powder.

SECTION XVIII. *Uranium.*

981. THE *native hydrated oxide* of this metal has been termed *uranite*, or *uranitic mica*. Its crystalline form is the cube, and several modifications; it often occurs in thin quadrangular plates. It exhibits various shades of yellow and green. It has been found in France; and of great beauty near Callington, in Cornwall.

982. The *native sulphuret of uranium* was formerly mistaken for an ore of zinc, and called *pechblende*, till Klaproth, in 1789, demonstrated it to contain uranium combined with sulphur. From this ore uranium may be obtained by the following process: Reduce it to powder, and expose it to heat in a muffle; then digest in dilute nitro-muriatic acid, and precipitate by excess of ammonia, to retain oxide of copper; collect and wash the precipitate, and dry it at a heat approaching redness.

When exposed to a violent heat with a small quantity of charcoal powder, metallic uranium is obtained.

Uranium is of a grey colour, brittle, and very difficult of fusion; its specific gravity has not been ascertained with precision. Bucholz states it as = 9.0.—GEHLEN'S *Journal*, iv.

983. Very few experiments have hitherto been made upon this metal. The oxide precipitated from its nitric solution by alcalis is yellow, but by heating with charcoal it becomes black.

984. *Chloride*, *Muriate*, and *Chlorate of Uranium* have not been examined; nor is any thing known of the *Iodide* or *Iodate of Uranium*.

985. *Nitrate of Uranium*, formed by digesting the peroxide in dilute nitric acid, and crystallizing, forms yellow prismatic crystals, easily soluble deliquescent in a moist air, and containing, according to Bucholz,

61	oxide
25	acid
14	water
100	

986. *Subnitrate of Uranium*, upon the authority of Bucholz, is formed by heating the nitrate, which renders a part insoluble in water, and separates in the form of a yellow powder.

987. *Sulphuret of Uranium* exists native. Neither the *Hyposulphite* nor *Sulphite of Uranium* have been examined.

Sulphate of Uranium forms yellow prismatic crystals, decomposable by heat, and according to the analysis of Bucholz, consisting of

70 oxide
18 acid
12 water
———
100

988. According to the same authority, the peroxide of uranium consists of 80 metal + 20 oxygen = 100; so that if we consider it as containing one proportional of metal and two of oxygen, we obtain 64 as the representative number of uranium; and as it is probable that the protoxide contains half the quantity of oxygen, the oxides would consist respectively of 64 uranium + 8 oxygen, and 64 uranium + 16 oxygen; but these numbers are at variance with those derived from the analysis of the salts by the same author, and at all events are merely theoretical.

989. The salts of uranium have a yellow colour and an astringent metallic taste. Potassa forms in their solutions a yellow precipitate, and carbonate of potassa a white precipitate; both these precipitates are insoluble in excess of pure alcali, but dissolve in the carbonate. Ferrocyanate of potassa produces a rich brown precipitate in solutions of uranium, which is very characteristic.

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SECTION XIX. *Titanium.*

990. TITANIUM exists in the state of oxide in two minerals, in titanite and in menachanite.

Titanite is a nearly pure oxide of titanium; it is of a brown colour, and occurs embedded in the quartz and granite of primitive countries, and sometimes traverses rock crystals in fine hair-like filaments. In this country it occurs at Bedgellert, in Caernarvonshire; and near Killin, in Scotland. The finest specimens are those from the vicinity of Mont Blanc and St. Gothard.

The mineral, known by the name of *anatase*, *octoëdrite*, and *oysanite*, is nearly of the same nature as titanite. It is found in Bavaria, Norway, Switzerland, and in the valley of Oysans in France.

Menachanite consists principally of oxides of titanium and iron; it is found in the bed of a small stream at Menachan, in Cornwall. *Nigrine*, *iserine*, *rutilite*, and *sphene*, are also ores of titanium.

991. The metal may be obtained from titanite by fusion with potassa; the fused mass, washed with water, leaves oxide of titanium, containing a little iron; it is to be dissolved in muriatic acid, and precipitated by oxalic acid. The oxalate affords the metal by intense ignition with charcoal: it is, however, scarcely possible to obtain it in any state of agglutination: in some trials made in the Royal Institution, nothing like globules of the metal could be procured, and the crucibles were always fused.

992. From menachanite, white oxide of titanium may be obtained

by fusing it with potassa, and adding muriatic acid to the alcaline solution.

993. Titanium is of the colour of copper. It is said to be susceptible of three degrees of oxidizement, the colours of the oxides being blue, red, and white.

The *blue* is formed by exposing the metal to heat and air; the *red* is the native oxide; and the *white* is that which is precipitated from the alcaline solution of titanite and menachanite by muriatic acid. According to Vauquelin and Hecht, (*Journal des Mines*, No. xv.) the white oxide contains 89 parts of red oxide and 11 of oxygen.

994. The action of chlorine, of iodine, and of their acids, upon titanium, have not been examined. The *carbonate of titanium* dissolves in muriatic, nitric, and sulphuric acids, and phosphoric acid occasions a white precipitate in these solutions. Neither the *muriate*, *nitrate*, nor *sulphate*, are crystallizable. The solution of the muriate is speedily decomposed by exposure to light, and a white precipitate of oxide is formed in it.

995. When the native oxides of titanium are fused with carbonate of potassa, at a temperature not too high, a white *carbonate of titanium* is formed.

996. The solutions of titanium are colourless, and afford white precipitates with the alcalis; ferrocyanate of potassa gives a green precipitate, and infusion of galls a red one. Hydrosulphuret of ammonia occasions a greenish precipitate.

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SECTION XX. *Cerium.*

997. THIS metal was obtained by Hisinger and Berzelius, from a mineral found at Bastnas in Sweden, to which they have given the name of *cerite*. It is also contained in *Allanite*, a mineral from Greenland, first distinguished as a peculiar species by Mr. Thomas Allan, of Edinburgh. It contains, according to Dr. Thomson's analysis, about 40 *per cent.* of oxide of cerium.

The ore is calcined, pulverized, and digested in nitro-muriatic acid. To the filtered solution saturated with potassa, oxalic acid is added, which occasions a precipitate; this, when dried and ignited, is oxide of cerium.

This oxide is extremely difficult of reduction. Mr. Children succeeded in fusing it by the aid of his powerful Voltaic apparatus, and when intensely heated it burned with a vivid flame, and was partly volatilized. Vauquelin describes cerium as a hard white brittle metal. —*Annales de Chimie*, Vol. iv.

998. Vauquelin and Hisinger have described two *oxides of cerium*. The *protoxide* is white, and consists of cerium 100 + oxygen 17.41. The *peroxide* is brown, and contains cerium 100 + oxygen 26.11. If we regard the first oxide as containing 1 proportional of metal + 2 of oxygen, and the second, 1 + 3, then the number representing cerium will be 91.9 and the oxides will consist respectively of 91.9 cerium + 16 oxygen, and 91.9 cerium + 24 oxygen.

999. Muriatic and sulphuric acids dissolve the red peroxide of cerium: the solutions afford yellow crystals. The muriate is deliquescent; the sulphate difficultly soluble. The Sulphate of the protoxide forms white crystals of a sweet taste. Nitric acid forms with the protoxide a deliquescent compound, of a sweet taste. The carbonate is precipitated from these solutions in the form of a white powder.

1000. The salts of cerium are either white or yellow, as they contain either the protoxide or peroxide. Their neutral solutions taste sweet. Ferrocyanate of potassa, and oxalate of ammonia, produce white precipitates soluble in nitric and muriatic acids. Neither sulphuretted hydrogen, nor gallic acid, occasion any precipitate.

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Section XXI. *Tellurium.*

1001. The ores of tellurium are, 1. *Native*, in which the metal is combined with iron and a little gold. 2. *Graphic ore*, which consists of tellurium, gold, and silver. 3. *Yellow ore*, a compound of tellurium, gold, lead, and silver; and 4. *Black ore*, consisting of the same metals with copper and sulphur.

These ores have only been found in the Transylvanian mines, and in Siberia.

The metal is extracted from them by precipitating their diluted nitro-muriatic solution by potassa, which is added in excess; the clear liquor is poured off and saturated with muriatic acid, which affords a precipitate of oxide of tellurium. This heated in a glass retort with charcoal, furnishes the metal. Tellurium is of a bright grey colour, brittle, easily fusible, and very volatile. Its specific gravity is 6.1.

1002. *Oxide of Tellurium.*—Exposed to heat and air, tellurium readily burns, exhaling a peculiar odour, and forming a yellowish white oxide, consisting according to Klaproth, (*Beiträge*, Vol. iii.) of

Tellurium	100
Oxygen	20.5

Hence the number 39 may be adopted as the representative of the metal; and if the above be considered a protoxide, it will contain

1 proportional of tellurium	=	39
1 ———— of oxygen	=	8
Oxide of tellurium	=	47

1003. *Chloride of Tellurium* is a white fusible compound, formed by heating the metal in chlorine. According to Davy, (*Elements*, p. 410.) it consists of 2 tellurium + 1.85 chlorine, which would give 1 proportional of each of its components, or

Tellurium	39
Chlorine	36
Chloride of tellurium	75

The *Chlorate of Tellurium* is not known.

1004. Iodine readily combines with tellurium, forming a deep brown *iodide*, which dissolves in water, forming the *hydriodate of tellurium*. The *Iodate of Tellurium* has not been examined.

1005. The salts of tellurium are decomposed by the alcalis, and the precipitate is re-dissolved when they are added in excess. Hydrosulphuret of ammonia forms a brown precipitate; ferrocyanate of potassa occasions no change. Zinc or iron, immersed into the solutions, cause the separation of metallic tellurium.

1006. Tellurium combines with hydrogen, producing *telluretted hydrogen gas*. The soluble salts of tellurium furnish white precipitates when neutralized by alcalis, which are soluble in excess either of the solvent or precipitant.

1007. The oxide of tellurium is readily soluble in muriatic, nitric, and sulphuric acids. The muriate affords a precipitate on the addition of water.—Berzelius, Nicholson's *Journal*, xxxvi.

1008. The oxide of tellurium combines with many of the metallic oxides, acting the part of an acid, and producing a class of compounds which have been called *tellurates*.

1009. *Tellurate of Potassa* may be formed by heating oxide of tellurium with nitre, and dissolving the residuum in boiling water, which, on cooling, deposits an imperfectly crystallized white powder, difficultly soluble in water.

1010. Solution of telluriate of potassa, added to solutions of lime, baryta, strontia, copper, and lead, forms insoluble tellurates of the oxides of those metals.

Section XXII. *Selenium.*

1011. This body is placed, rather from analogy than experiment, among the metals. It was discovered by Berzelius in the sulphur of Fahlun in Sweden, and was first suspected to be tellurium. Its colour is grey; its lustre bright metallic. It fuses at a few degrees above the boiling point of water, and when slowly cooled, assumes a granular fracture. It boils and evaporates in close vessels at a temperature a little below redness. Heated before the blow-pipe it volatilizes with a very powerful and peculiar smell, somewhat like that of horse-radish.

Selenium unites with the metals. With potassium it combines with great energy, producing a greyish compound, with metallic lustre, and which, when thrown into water, evolves *selenuretted hydrogen gas*, which is highly irritating to the nostrils. It combines both in the dry and humid way with the fixed alcalis, and forms red compounds. Heated to dryness with nitric acid it forms a volatile and crystallizable compound, called *selenic acid*, which unites to some of the metallic oxides, producing a distinct class of *seleniates*.—*Annales de Chimie et Physique*, Tom. vii.; Thomson's *Annals*, Vol. xi. and xii.

SECTION XXIII. *Arsenic.*

Mode of obtaining.

1012. THIS metal may be obtained from the white arsenic of commerce, by mixing it with half its weight of black flux*, and introducing the mixture into a Florence flask, placed in a sand bath, gradually raised to a red heat: a brilliant metallic sublimate of pure arsenic collects in the upper part of the flask. The volatility of white arsenic prevents its easy reduction by charcoal alone; but the potassa in the flux enables it to acquire a temperature sufficient for its perfect reduction.

Characters.

1013. Arsenic is of a steel blue colour, quite brittle, and of a specific gravity = 8.3. It readily fuses, and in close vessels may be distilled at a temperature of 360°, which is lower than its fusing point. Its vapour has a very strong smell, resembling that of garlic. Heated in the air it easily takes fire, burns with a blue flame, and produces copious white fumes of oxide. Exposed to a moist air it gradually becomes incrusted with a grey powder, which is an imperfect oxide. This metal and all its compounds are virulent poisons.

1014. *Native arsenic* has been found in Saxony, Hanover, France, Bohemia, and Cornwall. It usually occurs in rounded masses, or nodules, of a foliated lamellar texture, in the veins of primitive rocks, and is often associated with silver, cobalt, lead, and nickel ores.

1015. Arsenic and Oxygen.—There are two definite compounds of arsenic and oxygen, which are both capable of forming combinations with other metallic oxides. They are sour and soluble in water, and have thence been properly termed *arsenious* and *arsenic acids.*

The arsenious acid, or, as it is commonly called, *white arsenic*, or *white oxide of arsenic*, is the best known, and most commonly occurring compound of this metal; and as cases of poisoning by it are frequent, every person should be well acquainted with its characteristic properties.

1016. Arsenious acid may easily be procured by the combustion of the metal; but as it is formed during certain metallurgic processes, that mode is rarely resorted to. It is abundantly prepared at Joachimsthal in Bohemia, from arsenical cobalt ores, which are roasted in reverberatory furnaces, and the vapours condensed in a long chimney, the contents of which, submitted to a second sublimation, afford the *white arsenic* of commerce.

1017. Arsenious acid is white, semi-transparent, brittle, and of a vitreous fracture. Its specific gravity is 3.7. Its taste is acrid, accompanied by a very nauseous sweetness, and it is virulently poisonous, producing inflammation and gangrene of the stomach and intestines; it also proves fatal when applied to a wound; and as the local injury is in neither case sufficient to cause death, it is probable that an induced affection of the nervous system and of the heart is the cause of the mischief. (BRODIE'S *Observations and Experiments on the Action of Poi-*

Black flux.

* This is an extremely useful compound for effecting the reduction of many of the metallic oxides. It consists of charcoal and subcarbonate of potassa, and is best prepared by deflagrating in a crucible a mixture of one part of nitre and two of powdered tartar. The mixture remains in fusion at a red heat, and thus suffers the small globules of reduced metal to coalesce into a button.

sons.—Phil, Trans., 1812.) To get rid of the poison by producing copious vomiting and purging, and to pursue the usual means for subduing and preventing inflammation, are the principal points of treatment to be adopted in cases where this poison has been taken.—ORFILA, *Traité des Poisons*, Tom. i. p. 123.

1018. By a slow sublimation arsenious acid forms tetraëdral crystals: it is volatile at 380°, and has no smell when perfectly free from metallic arsenic. (Dr. PARIS, *Quarterly Journal of Science and Arts*, Vol. vi.) According to Klaproth, 1000 parts of water at 60° dissolve 2.5 of white arsenic; and 1000 parts of water at 212°, dissolve rather more than 77 parts, and about 30 parts are retained in permanent solution. The solutions taste acrid and nauseous, and redden vegetable blues. 80 parts of alcohol at 60°, dissolve one part of this acid. Its aqueous solution furnishes tetraëdral crystals by slow evaporation.

1019. The composition of the arsenious acid, as estimated by Proust, Thenard, and Thomson (THOMSON'S *System*, Vol. i. p. 295.) furnishes the following mean:

$$\overset{\text{Arsenic.}}{\overline{100}} + \overset{\text{Oxygen.}}{\overline{34}} = \overset{\text{Arsenious Acid.}}{\overline{134}}.$$

If we consider this acid as a compound of one proportional of arsenic and two of oxygen, we obtain the number 47.06 as the representative of arsenic; for

$$34 : 100 : : 16 : 47.06^{*}.$$

Without material error, therefore, we may adopt 47 as the representative of this metal, and the arsenious acid will then consist of 47 arsenic + 16 oxygen = 63.

1020. *Native White Arsenic* occurs in prismatic crystals, and in a pulverulent form: it is found in Saxony and Hungary.

1021. The arsenious acid forms a distinct class of salts, called *arsenites*, which have been but little examined.

The *arsenites of ammonia*, *potassa*, and *soda*, are easily soluble and uncrystallizable: they are formed by boiling the acid in the alcaline solutions. Those of *lime*, *baryta*, *strontia*, and *magnesia*, are difficultly soluble, and formed in the same way. Arsenite of potassa is the active ingredient in the *liquor arsenicalis* of the *Pharmacopœia*, and in *Fowler's mineral solution* or *tasteless ague drop*.

Arsenite of ammonia produces a yellow precipitate in nitrate of silver, easily soluble in excess of ammonia.

Arsenite of potassa produces a white precipitate in the white salts of manganese; a dingy green precipitate in the solutions of iron; a white precipitate in solutions of zinc and tin. Mixed with a solution of sulphate of copper, a precipitate of a fine apple-green colour falls, called from its discoverer, *Scheele's green*, and is useful as a pigment. In the solutions of lead, antimony, and bismuth, it forms white precipitates: added to nitrate of cobalt it forms a pink precipitate; and bright yel-

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[*] Thomson gives the composition of arsenic acid 4.75 arsenic + 3 atoms oxygen, (hence when the atom of hydrogen = 1), the atom of arsenic will be 38, and the arsenic acid 38 + 24=62, so also arseniceous acid will be 38+16=54, this last number seems preferable to 63, but no substitution has appeared proper as the numbers in the text are deduced from particular experiments.

low, with nitrate of uranium. With nitrate of silver it forms a white precipitate, soon becoming yellow, and very soluble in ammonia. All these precipitates are probably *arsenites* of the respective metals, and, heated by a blow-pipe on charcoal, they exhale the smell of arsenic.

Native Arsenite of Lead is found in France, in Spain, and in Siberia.

1022. *Arsenic Acid* is obtained by distilling a mixture of 4 parts of muriatic and 24 of nitric acid off 8 parts of arsenious acid, gradually raising the bottom of the retort to a red heat at the end of the operation. It may also be procured by distilling nitric acid off powdered metallic arsenic.

1023. Arsenic acid is a white substance, of a sour taste; it is deliquescent and uncrystallizable. Its specific gravity is 3.4. It requires for solution 6 parts of cold and 2 of boiling water; its solution reddens vegetable blues, and tastes acrid and metallic.

1024. It appears, from the experiments of Proust and Thomson, that the oxygen in the arsenic acid is, to that in the arsenious acid, as 3 to 2; hence we may regard it as a compound of 1 proportional of arsenic = 47, and 3 proportionals of oxygen = 24, and its representative number will be 71.

1025. The *Arseniates* are produced by the union of this acid with the metallic oxides; and many which are insoluble may be formed by adding arseniate of potassa to their respective solutions.

1026. *Arseniate of Ammonia* is formed by saturating arsenic acid with ammonia; rhomboidal prisms are obtained on evaporation, which, when gently heated, effloresce and evolve ammonia: at a higher temperature water is formed, oxide of arsenic sublimes, and nitrogen is evolved, a circumstance first observed by Scheele.

1027. *Arseniate of Potassa* is deliquescent and uncrystallizable.

1028. *Binarseniate of Potassa* may either be formed by adding excess of arsenic acid to potassa and evaporation; or by heating to redness, in a Florence flask, a mixture of equal parts of nitre and white arsenic; during the latter operation much nitrous gas is evolved, and on dissolving the residue in water, filtering, and evaporating, quadrangular crystals of binarseniate of potassa are obtained. Macquer was the first who thus procured this compound, hence it was termed *Macquer's neutral arsenical salt*. It is not easily decomposed by heat alone, and may be fused and kept red hot without undergoing other change than losing a little acid, but when mixed with about an eighth of charcoal powder and distilled, metallic arsenic rises, and carbonate of potassa, mixed with part of the charcoal, remains in the body of the retort. This salt is used in pharmacy for the cure of agues: it consists of

1 proportional of potassa	. . . . =	48
2 ———— arsenic acid	. . . . =	142
		190

1029. *Arseniate of Soda* is formed by saturating a solution of carbonate of soda with arsenic acid; on evaporation crystals are obtained, which appear to consist of

1 proportional of soda	. . . . =	32
1 ———— arsenic acid	. . . . =	71
		103

1030. *Arseniate of Lime* is deposited when arsenic acid is dropped into lime-water, or when arseniate of potassa is added to nitrate of lime; it is difficultly soluble in water, and consists, according to Laugier (*Annales de Chimie*, lxxxv. 58.) of

Arsenic acid	67
Lime	33

numbers which do not exactly correspond with 1 proportional of acid + 1 of base.

1031. *Arseniate of Baryta* may be formed by mixing arseniate of potassa with nitrate of baryta; when the acid is not in excess it is insoluble in water. It may be considered as a compound of 1 proportional of acid = 71 + 1 of baryta = 78.

1032. *Arseniate of Strontia* is formed as the last, and is insoluble.

1033. *Arseniate of Magnesia* is soluble, deliquescent, and uncrystallizable.

1034. *Arseniate of Manganese* is precipitated in the form of a white powder, when arseniate of potassa is added to muriate of manganese.

1035. *Arseniate of Iron.*—Arseniate of ammonia, added to the solutions of protosulphate and persulphate of iron, occasions greenish precipitates of *protarseniate* and *perarseniate* of iron both of which have been examined by Mr. Chenevix.—*Phil. Trans.*, 1801, pp. 220, 225.

1036. *Arseniate of Zinc* is precipitated in the form of a white insoluble powder when arsenic acid, or an alcaline arseniate is added to sulphate of zinc.

1037. *Arseniate of Tin* is a white insoluble powder, precipitated by adding arseniate of potassa to muriate of tin.

1038. *Arseniate of Copper* is formed by adding an alcaline arseniate to nitrate of copper; it is a blue insoluble powder. The arseniates of copper have been submitted to an elaborate investigation by Mr. Chenevix (*Phil. Trans.*, 1801.); he has described five varieties, as shown in the following table.—Thomson's *System*, ii. 616.

	Acid.	Oxide.	Water.
Variety 1*st.*	1.	3.70	2.50
——— 2*d.*	1.	2.76	1.
——— 3*d.*	1.	1.72	0.70
——— 4*th.*	1.	1.80	0.53
——— 5*th.*	1.	0.88	0.60

Dr. Thomson considers these varieties as reducible to four sub-species, as follow: 1*st.* A subarseniate, composed of 1 atom acid + 3 atoms peroxide. 2*d.* A subarseniate, composed of 1 atom acid + 2 atoms peroxide. 3*d.* and 4*th.* A neutral arseniate, composed of 1 atom acid + 1 atom peroxide. 5*th.* A binarseniate, composed of 2 atoms acid + 1 atom peroxide.

1039. *Arseniate of Lead.* It may be formed by pouring arsenic acid into any of the soluble salts of lead, when it falls in the form of a white powder, insoluble in water, but soluble in dilute nitric acid; a circumstance which enables us in analyses to separate it from sulphate of lead, which is insoluble (888.) This compound is fusible without decomposition; but if it be heated with charcoal, both the lead and arsenic are reduced, and the latter evaporates. This compound consists, according to theory, of

Arsenic acid	38.5
Oxide of lead	61.5
	100.

Thenard's analysis (*Annales de Chimie*, i.) gives its component parts

Acid	35.7
Oxide	64.3
	100.0

1040. *Arseniate of Antimony.*—Nothing is known respecting the combinations of arsenic acid with either of the oxides of antimony.

1041. *Arseniate of Bismuth* falls as an insoluble white powder on adding arsenic acid to nitrate of bismuth.

1042. *Arseniate of Cobalt* is precipitated of a red colour by the addition of an alcaline arseniate to a soluble salt of cobalt.

1043. *Arseniate of Uranium* is thrown down of a straw colour when arseniate of potassa is added to nitrate of uranium.

1044. Several of the metallic arseniates are found *native*; of these the most important are, 1. The *arseniate of iron*, which occurs in Cornwall, usually in cubic crystals of various shades of green. 2. *Arseniate of copper*, of which there are two principal varieties, the green and blue. The green is found in flattened octoëdra, in hexaëdral tables, and in prisms with dihëdral summits. Sometimes it is massive, or fibrous, and radiated. The blue variety is tetraëdral, octoëdral, and rhombic. These beautiful minerals are almost peculiar to Cornwall. 3. *Arseniate of lead* occurs in small hexaëdral crystals, of a yellow, green, or brown colour, transparent, and of a resinous lustre. It has been found in Cornwall, France, and Spain. 4. *Arseniate of Cobalt*, or *peachblossom cobalt ore*, is a rare mineral found in Saxony and Cornwall.

1045. *Arsenic and Chlorine.*—*Chloride of arsenic* is formed by throwing finely-powdered arsenic into chlorine; the metal burns and forms a whitish deliquescent and volatile compound; it may also be obtained by distilling 6 parts of corrosive sublimate with 1 of powdered arsenic; the chloride passes into the receiver in the form of an unctuous fluid, formerly called *butter of arsenic*. Mixed with water, the chloride of arsenic is decomposed, and white oxide or arsenious acid is deposited, muriatic acid being at the same time produced. Hence it may be inferred, that the chlorine is to the arsenic in the same proportion as the oxygen, and, consequently, that it consists of 1 proportional of arsenic + 2 proportionals of chlorine, which, from Dr. Davy's experiments, appears to be the case. Chloride of arsenic therefore, is composed of

47 arsenic + 72 chlorine = 119 chloride of arsenic.

1046. *Chlorate of Arsenic* has not been examined.

1047. *Iodide of Arsenic*, obtained by heating the metal with excess of iodine, is of a deep red colour, and volatile. When acted upon by water, it produces hydriodic and arsenic acids, whence it appears probable that it contains 1 proportional of arsenic and 3 of iodine.

1048. The action of iodic acid on arsenic has not been examined.

1049. *Arsenic and Hydrogen.—Arsenuretted Hydrogen Gas.*—When arsenic is presented to nascent hydrogen, a portion of the metal combines with the gas. The compound is best obtained by adding a portion of metallic arsenic, or of white arsenic, to the mixture of zinc filings and dilute sulphuric acid, usually employed for the production of hydrogen. (227). The gas may be collected over water, by which it is not sensibly absorbed.

1050. The specific gravity of this gas is liable to vary according to the mode by which it is procured. I have always found it heaviest when obtained from a mixture of 4 parts of zinc, 1 of arsenic, and 3 of sulphuric acid, diluted with 4 or 5 of water. After standing a day over water, it deposits a small quantity of brown matter, which appears to be a *hydruret of arsenic*, and then has a specific gravity of from 12 to 14, hydrogen being = 1. This is considerably heavier than the usual estimation. If the gas were composed of 1 proportional of arsenic and two of hydrogen, without condensation, 100 cubical inches should weigh 51.75 grains, and its specific gravity to hydrogen would be 20.7. But Gay-Lussac and Thenard, (*Recherches Physico-Chimiques, Tom. i.* p. 230.) have shown by decomposing it by tin, that 100 parts expand to 140, which would still increase its specific gravity, it being probable that 3 volumes of hydrogen are condensed into 2. It is probable, therefore, that the gas, hitherto described under the name of arsenuretted hydrogen, is a mixture of the real compound with hydrogen.

1051. The gas obtained by the above-described process is expanded in volume and deposits arsenic at high temperatures: exposure to intense cold is said to occasion its liquefaction. It smells strongly alliaceous; it extinguishes a taper, and burns with a pale blue flame, depositing arsenic and its oxide. If detonated with about 4 volumes of oxygen, arsenious acid and water are formed. According to Stromeyer, (NICHOLSON's *Journal*, Vol. xix.) it requires for its perfect combustion 0.72 parts of its bulk of oxygen; but this is probably not sufficient to burn the arsenic.

1052. If bubbles of chlorine be passed up into a jar of arsenuretted hydrogen, standing over warm water, flame and explosion are often produced, muriatic acid is formed, and a brown hydruret is deposited; but if the gas be passed in the same way by successive bubbles into chlorine, no inflammation results, absorption takes place, and muriatic acid and chloride of arsenic are formed. If the chlorine be not very pure, and when the gases are cold, inflammation seldom follows their mixture.

1053. Chlorine, added to a mixture of sulphuretted with arsenuretted hydrogen, causes a deposit of red sulphuret of arsenic.

1054. Nitric acid suddenly decomposes arsenuretted hydrogen; water, oxide of arsenic, nitrous acid, and nitric oxide are the results.

1055. *Arsenic and Sulphur.*—By slowly fusing a mixture of metallic arsenic and sulphur, or by heating white arsenic with sulphur, a *red sulphuret of arsenic* is obtained. It is crystallizable, and of a vitreous fracture: its specific gravity is 3.4. It is usually known under the name of *realgar*, and occurs *native* in Germany and Switzerland, in veins of primitive rocks and among volcanic matter. Its primitive form is an acute octoëdron.

1056. If white arsenic be dissolved in muriatic acid, and precipitated by hydrosulphuret of ammonia, a fine yellow sulphuret of arsenic falls, which it appears only differs in form from realgar: it is usually called *orpiment*. According to Laugier, (*Annales de Chimie*, lxxxv.) these sulphurets are composed of about 58 arsenic and 42 sulphur, which differs little from 1 proportional and 2, or

47 arsenic + 32 sulphur = 79 sulphuret of arsenic.

1057. *Native Orpiment* is of a bright lemon or golden colour. It is generally massive and lamellar. It occurs both in primitive and secondary rocks in Suabia, Hungary, China, and South America.

1058. M. Braconnot has successfully employed an ammoniacal solution of sulphuret of arsenic as a dye stuff; the process he recommends is as follows: 1 part of sulphur, 2 of white arsenic, and 5 of pearlash, are to be fused in a crucible at a heat a little below redness: a yellow mass results, which is to be dissolved in hot water and filtered; the filtered solution, diluted with water, is to be treated with weak sulphuric acid, and will give a fine yellow precipitate, which easily dissolves in ammonia, forming a solution at first yellow, but becoming colourless on adding more ammonia. The wool, silk, cotton, or linen is to be dipped into this solution, more or less diluted according to the colour required, care being taken that no metallic vessels are used; on taking them out they are at first colourless, but as the ammonia evaporates become yellow; they are then to be freely exposed to the air, washed and dried. This colour is very permanent but soap impairs it.

1059. *Sulphuret of Arsenic and Iron* is found native in many parts of Europe. It is of a more silvery colour than iron pyrites, and when heated exhales the odour of arsenic. It is called *arsenical pyrites*, or *mis-pickel*.

1060. Nothing is known respecting the *Sulphite* or the *Hyposulphite of Arsenic*.

1061. Sulphuric acid is slowly decomposed when boiled upon arsenic. Sulphurous acid is evolved, and difficultly soluble crystalline grains of *sulphate of arsenic* are deposited as the solution cools.

1062. *Phosphuret of Arsenic* is formed by heating the metal, or its oxide, with phosphorus; it is grey and brittle.

1063. Neither the *Hypophosphite* nor *Phosphite of Arsenic* have been examined.

1064. *Phosphate of Arsenic* is formed in difficultly soluble crystalline grains, by boiling white arsenic in phosphoric acid.

1065. There appears to be no *Carbonate of Arsenic*.

1066. Arsenic forms alloys with most of the metals, and they are generally brittle. With potassium it forms a brownish compound, which, when put into water, evolves less hydrogen than pure potassium, in consequence of the formation of hydruret of arsenic. With sodium, the alloy is either brown and of an earthy aspect, or grey and metallic, according to the proportions of the metals: water acts upon it as upon the former. (GAY-LUSSAC and THENARD, *Recherches Physico-Chimiques*, Tom. i.) The alloy of arsenic and manganese is not known. With iron, zinc, and tin, it forms white brittle compounds; with copper it forms a white malleable alloy; with lead, a brittle compound of a lamellar texture; with antimony, the alloy is brittle, hard, and very fusible. It combines with bismuth, and probably with cobalt, but these alloys have not been examined.

1067. The separation of arsenic from other metals may generally be accomplished by deflagration with nitre, by which it is acidified, and the arseniate of potassa may afterwards be washed out by hot water.

1068. As arsenic, either accidentally or intentionally taken, is a very frequent cause of death, and often the subject of judicial inquiry, it becomes of importance to point out the most effectual modes of discovering its presence. Where arsenic proves fatal, it is very seldom found in the contents of the stomach after death, but is generally previously voided by vomiting or by stool; and we often can detect it in the matter thrown off the stomach, in the form of a white powder, subsiding in water. The inflammation of stomach which results is generally a secondary effect, and takes place equally, whether the poison be swallowed or applied to a wound.

If minute quantities of white powder be detected, however, in the stomach after death, or in the matter vomited, it is to be carefully collected, and treated as follows:

(*a.*) Mix a small portion of it with about two parts of black flux; introduce the mixture into a glass tube, and gradually heat it red-hot in the flame of a spirit-lamp. If arsenic be present, a *steel-coloured sublimate* will attach itself to the cooler part of the tube, which, heated in contact of air, evaporates in a *white smoke, strongly smelling of garlic.*

(*b.*) Boil the suspected matter in a little distilled water: and when the solution has cooled, add a few drops of solution of sulphuretted hydrogen. If arsenic be present, a *yellow precipitate* will appear.

(*c*) To the solution *b* add a drop of solution of subcarbonate of potassa and then a drop or two of solution of sulphate of copper. An *apple-green precipitate* indicates arsenic.

(*d.*) Add to the solution *b* a drop of nitrate of silver, and of solution of ammonia. A *yellow precipitate* indicates arsenic.

It must be observed in regard to these tests, that the first only is unequivocal, and that the appearances produced by the others may originate from the presence of other substances. When, however, all the above appearances ensue, no doubt of the existence of arsenic can be entertained. The several precipitates should be collected, and will, when placed upon a red-hot iron, exhale the peculiar smell of arsenic, The reader is referred for further particulars on this subject to HENRY's *Elements of Chemistry*, Vol. ii. p. 480, 8th edit.: to MURRAY's *System*, Vol. iii. p. 441, 4th edit.: to Dr. BOSTOCK's *Paper*, in the *Edinb. Med. and Surg. Journal*, Vol. v. p. 166: to Mr. HUME's *Essay*, in the *Phil. Mag.* Vol. xxxiii.; and *London Med. and Phys. Journal*, Vol. xxiii.: to Dr. MARCET's *Paper*, in the *Medico-Chirurgical Transactions*, Vol. ii.; and to Mr. SYLVESTER's *Observations*, in NICHOLSON's *Journal*, Vol. xxxiii.

SECTION XXIV. *Molybdenum.*

1069. THE sulphuret is the most common natural compound of this metal. To procure the metal, the native sulphuret is powdered and exposed under a red hot muffle, till converted into a grey powder, which is to be digested in ammonia, and the solution filtered and evaporated to dryness. The residuum is dissolved in nitric acid, re-evaporated to dryness, and violently heated with charcoal. The metal is of a whitish grey colour, and of excessively difficult fusion. According to Hielm, its specific gravity is 7.4; according to Bucholz, it is as high as 8.6.

1070. *Molybdenum and Oxygen.*—When exposed to heat and oxygen molybdenum is acidified, a white crystalline sublimate of *molybdic acid* being formed.

There are two other compounds of molybdenum with oxygen; the one *brownish black*, obtained by heating molybdic acid with charcoal; the other *blue*, and procured by immersing tin in solution of molybdic acid;

the black oxide consists of 47 M. + 8 oxygen
the blue (molybdous acid) 47 M. + 16
the white (molybdic acid) 47 M. + 24

Mr. Hatchett, in his *Experiments on the native Molybdate of Lead*, concludes the metal to be susceptible of four degrees of oxidizement. —*Phil. Trans.*, 1796.

The above numbers are taken from the analyses of Bucholz, corrected by some experiments of my own, on the molybdic acid; our results are very nearly similar.

1071. To obtain *molybdic acid*, the native sulphuret should be triturated, to reduce it, as far as possible, to powder, and distilled, with three or four parts of nitrc acid, to dryness. This operation should be repeated, till the ore is converted into an uniform white mass, which consists of molybdic, nitric, and sulphuric acids; the two latter may be expelled by a red heat, in a platinum crucible, and the remaining molybdic acid repeatedly washed with boiling water, in which it is little soluble, will be nearly pure. It may be rendered perfectly pure by solution in ammonia, precipitation by nitric acid, and exposure to heat.

1072. The molybdic acid, thus procured, is a white powder, of the specific gravity of 3.46, and requiring 960 parts of boiling water for its solution, which is yellow, reddens litmus, but has no sour taste. Heated to redness in an open vessel, it slowly sublimes, and condenses in brilliant yellowish scales. It dissolves in hot sulphuric acid, forming a solution, which is colourless while hot, but on cooling acquires a blue colour, which is heightened by the addition of soda. Its muriatic solution is pale yellowish green, but becomes blue when saturated by potassa.—HATCHETT, *Phil. Trans.* 1796.

1073. *Mobybdate of Ammonia* is not crystallizable, and when heated to redness the ammonia is driven off, and the acid converted into oxide of molybdenum.—BUCHOLZ, *Gehlen's Journal*, iv. 616.

1074. *Molybdate of Potassa* is formed by digesting the acid in potassa; or by heating to redness two parts of nitre with one of molybdic acid, and lixiviating the mass. The solution yields small rhomboidal crystals by evaporation, and affords a precipitate of molybdic acid, to muriatic, nitric, and sulphuric acids.

1075. *Molybdate of Soda* is more soluble than molybdate of potassa, and furnishes permanent and transparent crystals. In obtaining both these salts, a deposit of a yellowish powder ensues, which is probably a *bimolybdate* of potassa and of soda.

1076. *Native Molybdate of Lead* occurs principally in crystals of different shades of yellow. It was first discovered in Carinthia, and has since been found in Mexico, Hungary, and Saxony. According to Mr. Hatchett's analysis (*Phil. Trans.* 1796,) it contains 38 molybdic acid + 58.4 oxide of lead; and these numbers closely correspond with its theoretical composition, which should be 1 proportional of molybdic acid = 71 + 1 proportional of oxide of lead = 112.

1077. *Molybdate of silver, of mercury of lead*, and *of nickel*, may be procured by adding molybdic acid to the respective nitrates of those metals.

The remaining molybdates have either not been examined, or the accounts of their properties are too much at variance to be depended upon.

1078. *Sulphuret of Molybdenum* is a sectile compound of a metallic lustre, composed of 47 M. + 32 S.

The *native sulphuret* is found in Bohemia, Sweden, and near Mont Blanc, disseminated in a grey granite. It has been found in England, chiefly in Cornwall; and in Scotland, in Inverness-shire. It rarely occurs crystallized; generally massive, and made up of easily separable laminæ. It is soft and unctuous to the touch, and in colour *much like* lead. It is found exclusively in primitive rocks; generally in granite, and with quartz.

1079. Little is known concerning the salts of molybdenum.

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SECTION XXV. *Chromium.*

1080. CHROMIUM was discovered by Vauquelin in 1797. It may be obtained by intensely igniting its oxide with charcoal. Its colour resembles that of iron, and its specific gravity is 5.9. It is brittle and difficult of fusion.

1081. *Chromium and Oxygen.*—When chromium is exposed to the action of heat and air, it combines with oxygen, and a *green protoxide* is obtained. This oxide easily dissolves in acids.

1082. *Native Protoxide of Chromium* has been found in France, in the department of the Rhone, in the form of a green incrustation. It is the colouring matter of the emerald, and exists in a few other minerals.

1083. When nitrate of chromium is decomposed at a red heat, an insoluble *brown deutoxide* is formed. It does not dissolve in the acids; but when heated with muriatic acid, chlorine is evolved, and a muriate, containing the protoxide, is formed.

1084. *Peroxide of Chromium*, or *Chromic acid*, is most easily procured by the decomposition of the native *chromate of lead*, which may be effected by reducing it to a very fine powder, and boiling it in a solution of potassa or soda. An orange-coloured solution of the alcaline chromate is thus formed, to which sulphuric acid is to be added. On evaporation chrystals of chromic acid are formed, along with the sulphate of soda or of potassa. Or the acid may be obtained by adding nitrate of baryta to the chromate of potassa, and subsequently decomposing the chromate of baryta which falls, by sulphuric acid.

1085. Chromic acid may also be procured by the following process from native *chromate of iron*, which is a more common mineral than the chromate of lead. Reduce it to a fine powder, and expose it to a red heat for two hours, mixed with half its weight of nitre; wash the contents of the crucible, and add to the lixivium nitric acid sufficient to neutralize the excess of potassa: in this way a solution of nitrate and of chromate of potassa is obtained. Upon adding nitrate of mercury to this solution, *chromate of mercury* is precipitated in the form of a red powder, which, when washed, dried, and heated, is decomposed, and either chromic acid or oxide is obtained.

1086. Chromic acid is of a red colour; its taste is sour and metallic, and it may be obtained from its aqueous solutions in prismatic crystals, of a ruby colour. When heated red hot, it gives out a portion of oxygen, and becomes the green protoxide; it imparts colour to the ruby.

1087. *Native Chromate of Iron* has been found in small crystalline grains, of an octoëdral form. It commonly occurs massive, of a black colour, with a slight metallic lustre, and hard enough to cut glass. It has been found in Siberia, France, and America, and promises to become useful in the arts, as a source of some fine pigments.

1088. *Native chromate of Lead* is a very rare mineral, hitherto only found in the Uralian mountains in Siberia; it occurs in prismatic crystals, of a fine orange red colour, and is occasionally accompanied by small green crystals, supposed to be *chromite of lead*, or a combination of oxide of chrome and oxide of lead.

1089. Satisfactory experiments on the composition of the oxides of chromium *are still wanting. According to Vauquelin*, chromate of baryta consists of 62.2 baryta + 37.4 chromic acid, or, speaking in the equivalent numbers adopted in this work, of 1 proportional of baryta = 78 + 1 proportional of chromic acid 46.9.

According to Berzelius, the green oxide of chromium contains half the quantity of oxygen existing in the chromic acid. If, therefore, the latter be regarded as a deutoxide, the number 30.9 will represent chromium, and protoxide of chromium would consist of 30.9 chromium + 8 oxygen; and chromic acid of 30.9 chromium + 16 oxygen.

1090. The chromates of ammonia, potassa, soda, lime, and magnesia are soluble and crystallizable, and of an orange colour. The chromates of baryta and strontia are difficultly soluble, and may be formed by adding chromate of potassa or soda to their soluble saline compounds. The other insoluble metallic chromates may be formed in the same way, and their colours, which are various and beautiful, often enable us to judge of the nature of the metal present. Thus chromate of soda forms insoluble precipitates in solutions of silver, mercury, lead, copper, iron, and uranium; the colours are crimson, red, orange or yellow, apple-green, brown, and yellow. It forms no precipitate in solutions of nickel, zinc, tin, cobalt, gold, or platinum; whence, perhaps, it may be inferred, that the chromates of the latter metals are soluble.

The chromates are decomposed by muriatic, nitric, and sulphuric acids. Muriatic acid, heated with the chromates, evolves chlorine, the chromic acid being reduced to the state of oxide.

The most correct details respecting the chromates that have been published, are to be found in Vauquelin's *Essay.*—*Annales de Chimie*, lxx.

1091. The green oxide of chromium is occasionally used in porcelain and enamel painting; and the artificial chromate of lead forms a rich and durable yellow.

The remaining compounds of chromium are as yet unexamined.

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SECTION XXVI. *Tungsten.*

1092. THIS metal is obtained by exposing a mixture of tungstic acid and charcoal to a strong heat. It is difficult of fusion, very hard, brittle, and of an iron colour. Its specific gravity 17.5. By the action of heat and air, tungsten is converted into an oxide, which is of a yellow colour. It has been called by some *Scheelium*, by others *wolframium*.

1093. *Peroxide of Tungsten*, or *Tungstic Acid*, may be obtained from two native combinations; the one called *wolfram*, the other *tungstate of lime*.

Wolfram is found in primitive countries generally accompanying tin ores; its colour is brownish black; it occurs massive and crystallized, its primitive form being a rectangular parallelopiped. It abounds in Cornwall. It consists of tungstic acid united with oxides of iron, and and manganese. It may be decomposed by ignition with three times its weight of nitre; the fused mass, digested in boiling water and filtered, furnishes a solution, which upon the addition of muriatic acid, gives a precipitate regarded by Scheele as tungstic acid, but which in fact is a compound of muriatic and tungstic acids and potassa. Dissolve this in boiling carbonate of potassa, precipitate by muriatic acid, wash the precipitate, and digest it in nitric acid. Then wash and dry it, and it is pure tungstic acid.—BUCHOLZ, as quoted by THOMSON, *System*, ii. 122.

1094. *Native Tungstate of Lime* is a whitish semi-transparent substance, found in England, Saxony, Bohemia, and Sweden, and occurring crystallized and massive. Its most usual form is the octoëdron. It may be decomposed by fusion with four parts of carbonate of potassa, the fused mass is digested in about twelve parts of boiling water, and filtered. Nitric acid precipitates the peroxide.

1095. *Tungstic Acid*, or *Peroxide of Tungsten*, is tasteless and insoluble in water; its specific gravity is 6. When violently heated it becomes green, grey, and black, probably from the loss of oxygen. It combines with several of the metallic oxides, and was found by Guyton to give considerable permanence to vegetable colours; hence it probably might prove useful in the art of dyeing, were it more abundantly procurable.

According to Dr. Thomson (*System*, Vol. i. p. 553,) tungstic acid is a compound of

Tungsten	100
Oxygen	25

and he regards it as containing one proportional of metal and three of oxygen. Upon these data the number 90 would represent tungsten and the peroxide would contain.

96	tungsten	(one proportional)
24	oxygen	(three proportionals)
120	tungstic acid.	

And tungstate of lime would consist of

1	proportional of tungstic acid =	120
1	———— lime ..... =	28
		148

but this does not agree with Klaproth's experiments, who found tungstate of lime to consist of

77.5	acid
22.5	lime
100	

though it is consistent with Berzelius's statement, as reported by Thomson, and which probably is founded on calculation.

Some of the tungstates have been examined by Scheele, and others by Vauquelin and Hecht (*Journal des Mines*, No. 19,) but their history remains very imperfect.

1096. *Tungstate of Ammonia* is procured in crystalline scales, of a metallic taste, by digesting the acid in ammonia or its carbonate. It contains, according to Vauquelin, 78 of acid, and 22 ammonia and water.

1097. *Tungstate of Potassa* is uncrystallizable and deliquescent. The acids occasion precipitates in its solution, which are triple compounds of tungstic acid, potassa, and the acid used as precipitant. The *Nitrotungstate of Potassa* is the salt originally described by Scheele as tungstic acid. It dissolves in 20 parts of water, at 212°, and reddens litmus.

1098. *Tungstate of Soda* crystallizes in hexaëdral tables, soluble in 4 of cold, and 2 parts of boiling water, and of an acrid taste. Sulphuric, nitric, and muriatic acids occasion precipitates, as in the tungstate of potassa.

1099. *Tungstate of Lime*, *of Baryta*, and *of Strontia*, are insoluble white compounds.

1100. *Tungstate of Magnesia* is obtained by boiling the acid with magnesia, filtering, and evaporating; it cystallizes in pearly scales. The acids produce precipitates of triple compounds in its solution.

1101. *Tungstate of Manganese*, formed by adding tungstate of potassa to muriate of manganese, is an insoluble white powder (*John*, *Gehlen's Journal*, iv.) *Tungstate of Iron* is also insoluble: *Tungstate of Zinc* and *of Tin* have not been examined, nor have any of the reremaining tungstates been examined in their pure state.

The remaining compounds of tungsten have scarcely been investigated, and appear of little interest or importance.

SECTION XXVII. *Columbium.*

1102. THIS metal was first discovered by Mr. Hatchett in a mineral from North America. It is found combined with the oxides of iron and manganese, and also with yttria, in the minerals called *tantalite* and *yttro-tantalite.*

1103. Tantalite is chiefly found in octoëdral crystals, and in masses of a black or grey colour, in Finland. Its specific gravity is 7.9, and it contains, according to Ekeberg,

80	oxide of columbium
12	oxide of iron
8	oxide of manganese.

1104. Yttro-tantalite is found in Ytterby, in Sweden. It contains about 45 per cent. of oxide of columbium. Its colour is dark grey, its lustre shining and somewhat metallic.

1105. Columbium was discovered in these minerals by M. Ekeberg, and, considering it as a *new* metal, he called it *tantalum.* In 1809 (*Phil. Trans.*) Dr. Wollaston examined these and the original mineral in the British Museum, and demonstrated the identity of columbium and tantalum. As the former name was given to this body by its original discoverer, it is here retained.

1106. Columbium may be procured from columbite or tantalite, by the following process: Mix 5 parts of the finely-powdered mineral with 25 of carbonate of potassa, and 10 of borax; fuse the mixture, and when cold digest it in muriatic acid; this dissolves every thing except the oxide of columbium, which remains in the form of a white powder (WOLLASTON, *Phil. Trans.* 1809, p. 248.). From 5 grains of columbite, Dr. Wollaston obtained

Oxide of columbium	4 grains
——— iron	$\frac{3}{4}$
——— manganese	$\frac{1}{4}$

From 5 grains of tantalite he procured

Oxide of columbium	$4\frac{1}{4}$ grains
——— iron	$\frac{1}{2}$
——— manganese	$\frac{2}{16}$

1107. Berzelius is the only person who has obtained metallic columbium. He describes it as having the colour of iron, very hard and brittle, and burning at a red heat into a whitish oxide.

1108. The characters of white oxide of columbium are very well marked. It is nearly insoluble in muriatic, nitric, and sulphuric acids; it is very soluble in potassa, and carbonate of potassa; 8 grains of the latter, fused with 1 of the oxide, render it soluble in water. It is much less soluble in soda, and only retained while hot. From the readiness with which this oxide combines with potassa, Mr. Hatchett called it *columbic acid.*

1109. *Columbate of Potassa*, as appears from Mr. Hatchett's experiments, forms white glittering scales, like boracic acid. Acids precipitate the columbic acid from this solution.

1110. Infusion of galls, added to the solution of columbate of potassa produces a very characteristic orange-coloured precipitate. Neither ferro-cyanate of potassa, nor hydrosulphurets, occasion any change.

There is a character very peculiar to the oxide of columbium, which is its ready solubility, in tartaric, citric, and oxalic acids. In all these cases the newly precipitated oxide must be used, for when dried it becomes very intractable.

1111. According to Berzelius, 100 parts of columbium combine with 5.485 of oxygen; so that the representative of the metal in our numbers will be 145.8, and of the oxide $145.8 + 8 = 153.8$—Thomson, Vol. i. p. 558.

The remaining properties of columbium have not been investigated.

Section XXVIII. *Nickel.*

1112. Nickel is found native; combined with arsenic; and with arsenic acid. It is procured pure by the following process: Dissolve the impure metal, sold under the name of *Speiss*, in sulphuric acid, by adding the quantity of nitric acid necessary to produce the solution. Concentrate this solution, and set it aside; fine green crystals of sulphate of nickel make their appearance. Proceed in this manner till you have obtained a sufficient quantity of crystals. Dissolve them in water, and crystallize a second time. If they be now dissolved in water, and decomposed by an alcali, pure oxide of nickel will fall. Mix it with 3 *per cent.* of resin, make it into a paste with oil, and expose it to the most violent heat of a forge, in a charcoal crucible. A button of pure nickel will be obtained.—Thomson's *System*, i. 391.

1113. Nickel is a white metal, which acts upon the magnetic needle, and is itself capable of becoming a magnet. It is difficultly fusible, but absorbs oxygen readily when heated red-hot. It is malleable, and its specific gravity is about 8.5.

1114. *Oxide of Nickel* is obtained by adding potassa to the solution of the nitrate; a precipitate falls of a pale green colour which is a *hydrate*, or compound of oxide of nickel with water; this heated to redness, affords a grey oxide, consisting, according to Tuputi (*Annales de Chimie*, lxxx.) of 100 metal + 27 oxygen; or, in our equivalents, of 29.63 nickel $+ 8$ oxygen $= 37.63$*.

This *protoxide of nickel* easily dissolves in ammonia forming a sapphire blue solution; this property is often made use of to separate oxides of nickel and iron, the latter being insoluble in ammonia.

1115. According to Thenard, if chlorine be passed through a mixture of the hydrate of nickel and water, a black *peroxide* is formed, which, when acted upon by the acids, evolves oxygen, and returns to the state of protoxide,

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* Brandt has given no reason why he prefers Tuputi's experiments to those of Proust, Richter, Klaproth, &c. who respectively give 26. 28.2 and 32.5 for the oxygen united to 100 metal. Thomson in his chemistry deduces the atom of nickel from Tuputi's composition of the sulphate, and makes it 28 when hydrogen=1. But the atom deduced from the chloride and sulphate here given, is almost exactly=30.

1116. *Chloride of Nickel.*—When nickel is heated in chlorine a *chloride* results. This compound may also be obtained by heating muriate of nickel to redness in a glass tube; a yellow scaly body is obtained, consisting of 55.5 nickel + 67 chlorine, or 29.8 (1 proportional nickel) + 36 (1 proportional chlorine.)

1117. *Muriate of Nickel*, formed by dissolving the oxide or carbonate of nickel in muriatic acid, is obtained by evaporation in a confusedly crystalline mass, of an apple-green colour and sweetish taste; it is soluble in about 2 parts of water at 60°.

1118. *Chlorate of Nickel.*—Not examined.

1119. *Iodide of Nickel* may be formed by adding solution of hydriodate of potassa to sulphate or nitrate of nickel; it is of a greenish yellow colour, and insoluble.

1120. *Iodate of Nickel* has not been examined.

1121. *Nitrate of Nickel* is a green deliquescent salt, difficultly crystallizable in rhomboids. The analyses of this salt are much at variance, but it probably consists of 1 proportional of each of its components, or

37.8 oxide of nickel
54 nitric acid
———
91.8

The crystals contain 3 proportionals of water.

1122. By adding excess of ammonia to nitrate of nickel, and evaporating, green crystals of *ammonio-nitrate of nickel* are obtained, the solution of which affords no precipitate with potassa or soda.

1123. *Sulphuret of Nickel* may be formed by fusion. It is a brittle yellow compound.

1124. Neither the *Hyposulpite* nor the *Sulphite of Nickel* have been examined.

1125. *Sulphate of Nickel* is formed by digesting the oxide in dilute sulphuric acid. A bright green solution is formed, which affords quadrangular prismatic crystals, soluble in about 3 parts of water at 60°, and which effloresce by exposure. Their taste is sweet and astringent. This salt is also obtained by heating common nickel in sulphuric acid, with the occasional addition of nitric acid. (1112.)

The crystallized sulphate of nickel contains 7 proportionals of water, and is composed as follows:

1 proportional of oxide = 37.86
1 ———— acid = 40
7 ———— water = 63
———
140.86*

1126. *Sulphate of Ammonia and Nickel* is formed by evaporating a mixed solution of ammonia, and sulphate of nickel; it forms four-sided prismatic crystals.

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* According to the composition of the sulphate as determined by Tuputi, (see *Thomson's chem.* article *nickel*) the acid is to the oxide as 40 : 34.9, and not as 40 : 37.86.

1127. *Sulphate of potassa and Nickel* is obtained by adding potassa to sulphate of nickel (not in excess,) filtering and evaporating. It forms green rhomboidal crystals.

1128. *Sulphate of Nickel and Iron* is formed by dissolving the mixed protoxides in sulphuric acid. It is a green efflorescent salt, in tabular crystals.

1129. Sulphuretted hydrogen and hydrosulphuret of ammonia produce a black precipitate of *hydrosulphuretted oxide of nickel*, when added to the solution of the metal.

1130. *Phosphuret of Nickel* is a brittle whitish compound.

1131. *Hypophosphite* and *Phosphite of Nickel* remain unexamined.

1132. *Phosphate of Nickel* being nearly insoluble, is precipitated, upon adding phosphate of soda to a solution of nickel. It is of a pale green colour.

1133. *Carbonate of Nickel* is precipitated in the form of a green powder, when carbonate of potassa is added to sulphate of nickel. It is probably a compound of 1 proportional of each of its components.

35.5	oxide of nickel
20.7	carbonic acid
56.2	

1134. *Borate of Nickel* is a pale green insoluble compound.

1135. Ferrocyanate of potassa occasions a very characteristic pale grey precipitate in dilute solutions of nickel: in concentrated solutions the precipitate is pale green.

1136. Arseniate of potassa, dropped into nitrate of nickel, occasions the precipitation of a pale green *arseniate of nickel*.

1137. The salts of nickel are distinguished by the fine green colour of their solutions, and by affording a green precipitate with ammonia, soluble in excess of that alcali, when it assumes a blue colour. The yellow green precipitate afforded by hydriodate of potassa is very characteristic of nickel; but the nicest test of its presence is the ferrocyanate of potassa, which produces a pale grey or greenish white precipitate in all the solutions of the metal.

1138. Of the *Alloys of Nickel* there is one which requires particular notice, namely, that with iron, which forms the principal metallic ingredient in those lapideous masses, which, in different countries, have fallen upon our globe, and which have been termed *aërolites*, or *meteoric stones*. Though we really know nothing of the source or origin of these bodies, it has been ascertained upon the most satisfactory and indisputable evidence, that they are not of terrestrial formation; and, consequently, since men began to think and reason correctly, their visits to our planet have awakened much speculation, and some experimental research. Meteoric stones.

In the first place, it deserves to be remarked, that we have very distinct evidence of the falling of stony bodies from the atmosphere in various countries, and at very remote periods. For, to say nothing of the fabulous narrations which encumber the annals of ancient Rome, or the extended catalogue of wonders flowing from the lively imagination of oriental writers, such events are recorded in holy writ, and have been set down by the most accredited of the early historians; and although philosophic scepticism long contended against the admission of the fact, it has in modern times received such unanswerable proofs, as to be allowed by all who have candidly considered the evidence, and is only rejected by the really ignorant, or by those who, for the sake of singularity, affect disbelief.

The first tolerably accurate narration of the fall of a meteoric stone relates to that of Ensisheim, near Basle, upon the Rhine. The account which is deposited in the church runs thus: A.D. 1492, Wednesday, 7 November, there was a loud clap of thunder, and a child saw a stone fall from heaven: it struck into a field of wheat, and did no harm, but made a hole there. The noise it made was heard at Lucerne, Tilling, and other places; on the Monday, King Maximilian ordered the stone to be brought to the castle, and after having conversed about it with the noblemen, said the people of Ensisheim should hang it up in their church, and his Royal Excellency strictly forbade any body to take any thing from it. His Excellency, however, took two pieces himself, and sent another to Duke Sigismund of Austria. This stone weighed 255 lbs.

In 1627, 27th November, the celebrated Gassendi saw a burning stone fall on Mount Vaisir, in Provence: he found it to weigh 59 lbs.

In 1672, a stone fell near Verona, weighing 300 lbs. And Lucas, when at Larissa, in 1706, describes the falling of a stone, with a loud hissing noise, and smelling of sulphur.

In September, 1753, de Lelande witnessed this extraordinary phænomenon, near Pont de Vesle. In 1768, no less than three stones fell in different parts of France. In 1790, there was a shower of stones near Agen, witnessed by M. Darcet, and several other respectable persons. And on the 18th of December, 1795, a stone fell near Major Topham's house, in Yorkshire; it was seen by a ploughman and two other persons, who immediately dug it out of the hole it had buried itself in; it weighed 56 lbs.

We have various other, and equally satisfactory, accounts of the same kind. All concur in describing a luminous meteor, moving through the air in a more or less oblique direction, attended by a hissing noise, and the fall of stony or semi-metallic masses, in a state of ignition. We have, however, evidence of another kind, amply proving the peculiarities of these bodies. It is, that although they have fallen in very different countries, and at distant periods, when submitted to chemical analysis they all agree in component parts; the metallic particles being composed chiefly of nickel and iron; the earthy, of silica and magnesia.

1139. Large masses of *native iron* (721) have been found in different parts of the world, of the history and origin of which nothing very accurate is known. Such are the great block of iron at Elbogen, in Bohemia; the large mass discovered by Pallas, weighing 1600 lbs., near Krasnorjark, in Siberia; that found by Goldberry, in the great desert of Zahra, in Africa; probably, also, that mentioned by Mr. Barrow, on the banks of the great fish river in Southern Africa; and those noticed by Celis, Bruce, Bougainville, Humboldt, and others in America, of enormous magnitude, exceeding 30 tons in weight. That these should be of the same source as the other meteoric stones, seems at first to startle belief; but when they are submitted to analysis, and the iron they contain found alloyed with nickel, it no longer seems credulous to regard them as of meteoric origin. We find nothing of the kind in the earth.

1140. To account for these uncommon visitations of metallic and lapideous bodies, a variety of hypotheses have been suggested:

Are they merely earthly matter, fused by lightning? Are they the offspring of any terrestial volcano? These were once favourite notions; but we know of no instance in which similar bodies have in that way been produced, nor do the lavas of known volcanoes in the least resemble these bodies; to say nothing of the inexplicable projectile force that would here be wanted. This is merely explaining what is puzzling, by assuming what is impossible; and the persons who have taken up this conjecture, have assumed one impossibility to account for what they conceive to be another, namely, that the stony bodies should come from any other source than our own globe.

The notion that these bodies come from the moon, is, when impartially considered, neither absurd nor impossible. It is quite true, that the quiet way in which they visit us is against such an origin; it seems, however, that any power which would move a body 6000 feet in a second, that is, about three times the velocity of a cannon-ball, would throw it from the sphere of the moon's attraction into that of our earth. The cause of this projective force may be a volcano, and if thus impelled, the body would reach us in about two days, and enter our atmosphere with a velocity of about 25000 feet in a second. Their ignition may be accounted for, either by supposing the heat generated by their motion in our atmosphere sufficient to ignite them, or by considering them as combustibles, ignited by the mere contact of air.

While we are considering the *possibility* of these opinions, it may be remembered, that in the great laboratory of the atmosphere, chemical changes *may* happen, attended by the *production* of iron and other metals; that, at all events, such a circumstance is within the range of possible occurrences; and that the meteoric bodies which thus salute the earth with stony showers, may be children of the air, created by the union of simpler forms of matter. The singular relationship between iron and nickel, and magnetism, and the uniform influence of meteoric phænomena on the magnetic needle, should be taken into account in these hypotheses.

1141. Meteoric stones have generally an uneven black surface, and are internally of a grey colour and course texture. When carefully examined, they appear made up of a number of small spherical bodies and metallic grains imbedded in a softer matter, composed, according to Mr. Howard, (*Phil. Trans.*, 1802.) of silica, magnesia, and iron with a little nickel: the spherical bodies are nearly of similar composition; and the metallic grains are partly *meteoric iron*, and partly the same with a little sulphur. In addition to these substances, Vauquelin found 2 *per cent.* of chrome in a stone which fell at Langres, in 1815, (*Ann. de Chim. et Phys.*, i. 53.) And Stromeyer detected cobalt in the meteoric iron from the Cape of Good Hope. (THOMSON's *Annals*, ix.) Lime and alumine have also been found in them, and a small proportion of manganese. M. Laugier has lately announced the existence of a meteoric stone without nickel, but containing chrome; and as he has detected the latter metal in all the aërolites which he has examined, he considers it as their most characteristic ingredient.—*Mem. du Museum*, vi.

1142. In meteoric iron the proportion of nickel varies considerably. In a specimen from the Arctic region I found 3.2 *per cent.* (*Quarterly Journal*, vi. 369.) In that from Siberia, Mr. Children found nearly

10 *per cent.* The analysis may be performed by solution in nitro-muriatic acid; the iron is thrown down by excess of ammonia in the state of peroxide, of which 100 grains indicate 70 of metallic iron; it is separated by filtration, washed and dried, and on evaporating the filtrated liquor and heating its dry residue red-hot, the oxide of nickel is obtained, which should be re-dissolved in nitric acid and precipitated by pure potassa, the mixture being boiled for a few seconds. 100 grains of this oxide of nickel are equal to 79 of metallic nickel.—CHILDREN, *Quarterly Journal*, ix. 324.

1143. Meteoric iron has been imitated by fusing iron with nickel. The alloy of 90 iron with 10 nickel is of a whitish yellow cast, and not so malleable as pure iron. The alloy with 3 *per cent.* of nickel is perfectly malleable and whiter than iron. These alloys are less disposed to rust than pure iron, but nickel alloyed with steel increases the tendency to rust.—STODART and FARADAY, *Quarterly Journal of Science and Arts*, ix.

1144. The remaining alloys of nickel have been little examined. Nothing is known of its compounds with potassium, sodium, manganese, zinc, or tin. With copper it forms a hard white alloy, which appears to be the *white copper* of the Chinese. Its other alloys have not been examined.

SECTION XXIX. *Mercury.*

1145. THE principal ore of this metal is the sulphuret, or *native cinnabar*, from which the mercury is separated by distillation with quicklime or iron filings.

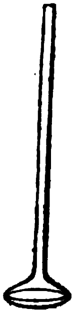
Characters. Mercury is a brilliant white metal, having much of the colour of silver, whence the terms *hydrargyrum*, *argentum vivum*, and *quicksilver*. It has been known from very remote ages. It is liquid at all common temperatures, solid and malleable at—40°, and it boils and becomes vapour at about 670°. Its specific gravity is 13.5.

1146. Mercury is sometimes adulterated with the alloy of lead and bismuth, a fraud easily detected by the want of its due fluidity, and by its not being perfectly volatile, but leaving a residuum when boiled in a platinum or iron spoon. The best method of purifying mercury is to re-distil it in an iron retort.

1147. *Native Mercury* occurs in small fluid globules, in most of the mines producing the ores of this metal.

1148. *Mercury and Oxygen.*—There are two oxides of mercury. The *black*, or *protoxide*, may be obtained by long agitation of the metal in contact with oxygen, or by washing the *chloride of mercury* (calomel) with hot lime-water. It is insipid, and insoluble in water, and was called in old pharmacy, *Ethiops per se.*

1149. The *red* or *peroxide* of mercury is produced by exposing the metal, heated nearly to its boiling point, to the action of air. It becomes coated with reddish brown scales, spangles, and crystals, and is ultimately entirely converted into a red shining mass, called in old pharmaceutical works, *precipitate per se*, or *calcined mercury.* It is the *hydrargyri oxydum rubrum* of the present *London Pharmacopœia*. It is most easily obtained by introducing into a flat-bottomed matrass, of the annexed shape, about 4 ounces of mercury, and placing it in a sand bath, heated to the boiling point of the metal. In about a month's time nearly the whole is converted into oxide. Air is freely admitted by the tube, while its length prevents the escape of mercurial vapour, which condenses and falls back into the body of the vessel; the remaining portion of running mercury may be driven off by exposing it in a basin to a heat just below redness.



1150. Peroxide of mercury has an acrid metallic taste, and is poisonous; it dissolves very sparingly in water. When heated, it acquires a black colour, but becomes again red on cooling; at a red heat it evolves oxygen, and is reduced to the metallic state. It should be entirely volatilized when placed upon a red-hot iron, for it is sometimes adulterated with red lead.

1151. Though it is difficult to obtain a perfectly pure black oxide of mercury, it appears to have been demonstrated that it contains just half the quantity of oxygen contained in the red oxide.

The best analyses of the red oxide give as its component parts,

Mercury	92.7
Oxygen	7.3
	100.0*

or more correctly 100 mercury + 8 oxygen.

If we consider this as a compound of 1 proportional of mercury and 2 of oxygen, we obtain the number 200 as the representative of mercury; for

8 : 100 :: 16 : 200.

The protoxide, therefore, will consist of

200 Mercury + 8 Oxygen = 208 Protoxide.

And the peroxide of

200 Mercury + 16 Oxygen = 216 Peroxide.

The black oxide exists in the *pilula hydrargyri*, and in the mercurial ointment of the *Pharmacopœia*.

1152. *Mercury and Chlorine* combine in 2 proportions, and a protochloride and perchloride of mercury are the results. These compounds are usually called *calomel* and *corrosive sublimate*. In the *London Pharmacopœia* they have received the improper names of *submuriate of mercury* and *oxymuriate of mercury*.

1153. *Protochloride of Mercury.*—This compound, commonly termed *calomel*, is first mentioned by Crollius, early in the seventeenth centu-

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[*] This proportion would make but 7.87 oxygen unite to 100 mercury. Thomson, in his paper (*Ann. Ph.* for Aug. 1821.) has shown that the proportion is 100 mercury + 8 oxygen. In the same paper he states the experiment of Safstrom = 100 mercury + 7.99. Thomson's numbers will therefore be adopted.

ry. The first directions for its preparation are given by Beguin, in the *Tyrocinium Chemicum*, published in 1608. He calls it *draco mitigatus.* Several other fanciful names have been applied to it, such as *aquila mitigata, manna metallorum, panchymagogum minerale, sublimatum dulce, mercurius dulcis*, &c.

The most usual mode of preparing calomel consists in triturating two parts of corrosive sublimate with one of mercury, until the globules disappear, and the whole assumes the appearance of an homogeneous grey powder, which is introduced into a matrass, placed in a sand heat, and gradually raised to redness. The calomel sublimes, mixed with a little corrosive sublimate, the greater part of which, however, being more volatile than the calomel, rises higher in the matrass; that which adheres to the calomel may be separated, by reducing the whole to a fine powder, and washing in large quantities of hot distilled water. Pure calomel, in the form of a yellowish white insipid powder, remains.

It was formerly the custom to submit calomel to very numerous sublimations, under the idea of rendering it *mild;* but these often tended to the production of corrosive sublimate; and the calomel of the first sublimation, especially if a little excess of mercury be found in it, is often more pure than that afforded by subsequent operations.

1154. The following are the directions given in the last *London Pharmacopœia:*

"Take of oxymuriate of mercury, 1 lb.
——— purified mercury, *by weight*, 9 oz.

Rub them together, until the metallic globules disappear; then sublime: take out the sublimed mass, reduce it to powder, and sublime it in the same manner twice more successively. Lastly, bring it to the state of a very fine powder; throw this into a large vessel, full of water; then stir it, and, after a short interval, pour the supernatant turbid solution into another vessel, and set it by, that the powder may subside. Lastly, having poured away the water, dry the powder."—POWELL's *Translation of the London Pharmacopœia*, Lond. 1815. p. 144 and 99.

1155. It will be observed, that in these processes the operation consists in reducing the perchloride to the state of protochloride by the addition of mercury. Various modes have, however, been adopted for the direct formation of calomel: two of these may here be noticed, of which the first is in the humid way, as devised by Scheele and Chenevix. It is as follows:

Form a nitrate of mercury, by dissolving as much mercury as possible in hot nitric acid; then dissolve in boiling water a quantity of common salt, equal to half the weight of the mercury used, and render the solution sensibly sour by muriatic acid, and pour the hot nitrate of mercury into it. Wash and dry the precipitate.

If this process be carefully performed, and the precipitate thoroughly edulcorated, the calomel is sufficiently pure.

1156. The second process, however, or that by which calomel is directly formed in the dry way, appears, on the whole, the least exceptionable for the production of this very important article of pharmacy; it is the method followed at Apothecaries' Hall, sanction having been obtained for its adoption from the College of Physicians.

50 lbs. of mercury are boiled with 70 lbs. of sulphuric acid, to dryness, in a cast-iron vessel: 62 lbs. of the dry salt are triturated with

40½ lbs. of mercury, until the globules disappear, and 34 lbs. of common salt are then added. This mixture is submitted to heat in earthen vessels, and from 95 to 100 lbs. of calomel are the result. It is to be washed in large quantities of distilled water, after having been ground to a fine and impalpable powder.

1157. Protochloride of mercury is usually seen in the form of a white mass, of a crystalline texture; and when very slowly sublimed, it often presents regular four-sided prisms, perfectly transparent and colourless. Its specific gravity is 7.2. It is tasteless and very nearly insoluble in water. It can scarcely be called poisonous, since in considerable doses it only proves purgative. By exposure to light it becomes brown upon its surface. If scratched, it gives a yellow streak, which is very characteristic, and does not belong to the perchloride. When very finely levigated it becomes of a buff colour.

It consists of 1 proportional of mercury 200 + 1 proportional of chlorine 36, and its representative number is 236.

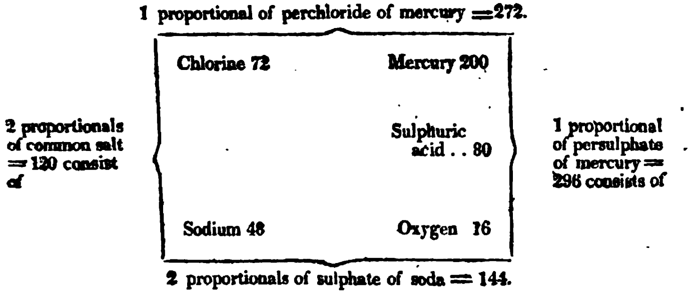
1158. *Native Chloride of Mercury* or *mercurial horn ore*, has been found in Germany, France, and Spain, usually crystallized, and sometimes incrusting and massive.

1159. *Perchloride of Mercury*, or *corrosive sublimate*, may be obtained by a variety of processes.

When mercury is heated in chlorine, it burns with a pale flame; the gas is absorbed, and a white volatile substance rises, which is the perchloride.

It may also be obtained by dissolving peroxide of mercury in muriatic acid, evaporating to dryness, re-dissolving in water, and crystallizing.

1160. The ordinary process for making corrosive sublimate consists in exposing a mixture of chloride of sodium (common salt) and persulphate of mercury, to heat in a flask, or other proper subliming vessel; a mutual decomposition ensues. The chlorine of the common salt unites to the mercury of the sulphate, and forms bi-chloride of mercury. The oxygen of the oxide of mercury converts the sodium of the salt into soda, which, with the sulphuric acid, produces sulphate of soda. This decomposition is exhibited by the following diagram:


1 proportional of perchloride of mercury = 272.
Chlorine 72
Mercury 200
2 proportionals of common salt = 120 consist of
Sulphuric acid . . 80
1 proportional of persulphate of mercury = 296 consists of
Sodium 48
Oxygen 16
2 proportionals of sulphate of soda = 144.

1161. The following are the official directions of the *London Pharmacopœia*, for the preparation of corrosive sublimate, there termed *oxymuriate of mercury*.

"Take of purified mercury, *by weight*, 2 lbs.
—— sulphuric acid, *by weight*, 30 oz.
—— dried muriate of soda, 4 lbs.

Boil the mercury with the sulphuric acid in a glass vessel, until the sulphate of mercury is left dry. Rub this when it is cold with the muriate of soda in an earthen-ware mortar; then sublime it in a glass cucurbit, increasing the heat gradually."—POWELL's *Translation.*

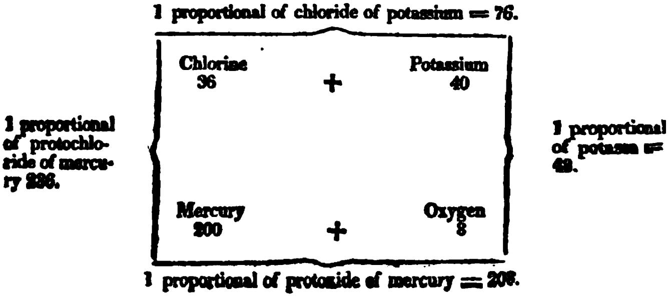
The quantity of common salt employed in this process is obviously too large; in practice, however, we find that more than the real quantity decomposed, and shown in the above table, is required.

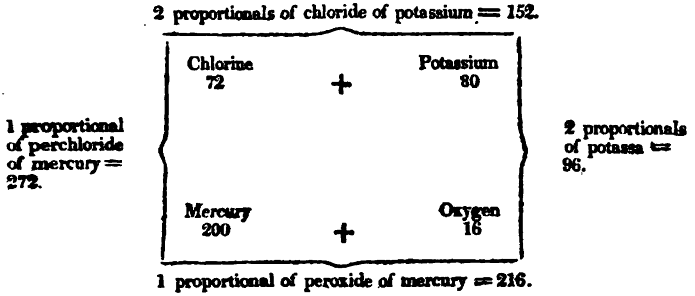
1162. The following is the process employed at Apothecaries' Hall for the formation of corrosive sublimate: 50 lbs. of mercury are boiled to dryness with 70 lbs. of sulphuric acid. 73 lbs. of persulphate of mercury are thus formed, which being perfectly mixed with 120 lbs. of common salt and sublimed, yield from 63 to 65 lbs. of corrosive sublimate.

1163. By the quantity of chlorine absorbed by a given weight of mercury, we learn that the perchloride of mercury consists of 1 proportional of mercury = 200 + 2 proportionals of chlorine = 72, consequently, its representative number is 272.

1164. Perchloride of mercury is usually seen in the form of a perfectly white semi-transparent mass, exhibiting the appearance of imperfect crystallization. It is sometimes procured in quadrangular prisms. Its specific gravity is 5.2. Its taste acrid and nauseous, and leaving a peculiar metallic and astringent flavour upon the tongue. It dissolves in 20 parts of water at 60°, and in about half its weight at 212°. It is more soluble in alcohol than in water. When heated, it readily sublimes in the form of a dense white vapour, strongly affecting the nose and mouth. It dissolves without decomposition in muriatic, nitric, and sulphuric acids: the alcalis and several of the metals decompose it. It produces, with muriate of ammonia, a very soluble compound; hence a solution of sal-ammoniac is used with advantage in washing calomel to free it from corrosive sublimate.

1165. Protochloride and perchloride of mercury are decomposed by potassa, soda, and lime; the former affords *black*, (*hydrargyri oxidum cinereum* of the *London Pharmacopœia*,) the latter *red*, oxide of mercury; and the chlorides of potassium, sodium, and calcium, are produced. The following diagrams shew the interchange of elements that takes place in the case of adding a solution of potassa to protochloride and perchloride of mercury.


1 proportional of chloride of potassium = 76.
Chlorine 36
+
Potassium 40
1 proportional of protochloride of mercury 236.
1 proportional of potassa = 48.
Mercury 200
+
Oxygen 8
1 proportional of protoxide of mercury = 208.


2 proportionals of chloride of potassium = 152.
Chlorine 72
+
Potassium 80
1 proportional of perchloride of mercury = 272.
2 proportionals of potassa = 96.
Mercury 200
+
Oxygen 16
1 proportional of peroxide of mercury = 216.

1166. When solution of ammonia is poured upon calomel, protoxide of mercury, and muriate of ammonia, are the results; but ammonia, added to a solution of corrosive sublimate, occasions a white precipitate of a *triple muriate of ammonia and mercury.*

A compound of this kind has long been used in pharmacy, under the name of *calx hydrargyri alba*, or *white precipitate.* The *London Pharmacopœia* directs the follow process for its formation.

" Take of oxymuriate mercury ¼ lb.
——— muriate of ammonia 4 oz.
——— solution of subcarbonate of potassa ½ pint.
——— distilled water 4 pints.

First dissolve the muriate of ammonia, then the oxymuriate of mercury, in the distilled water, and add thereto the solution of subcarbonate of potassa. Wash the precipitated powder until it becomes tasteless; then dry it."

1167. Muriate of ammonia renders corrosive sublimate more soluble in water, one part rendering five parts soluble in rather less than five of water. By evaporation a triple salt is obtained, formerly called *sal alembroth.* The addition of potassa or soda throws down the abovementioned white precipitate. Hence its use in washing calomel.

1168. *Chlorate of Mercury.*—Chloric acid dissolves both the oxides of mercury; the *protochlorate* has the appearance of a yellowish granular powder, sparingly soluble in hot water, and of a mercurial taste. The *perchlorate* forms white acicular crystals, having the acrid flavour of the perchloride.—VAUQUELIN, *Annales de Chimie*, XCV.

1169. *Mercury and Iodine* unite in two proportions. These compounds may be procured either by gently heating mercury with iodine, or by adding hydriodic acid to solutions of mercury. The *protiodide* is yellow, and the *periodide* red. They respectively consist of 1 proportional of mercury + 1 of iodine and 1 + 2. They are both insoluble in water.

1170. *Iodate of Mercury.*—Iodate of potassa occasions a precipitate in protonitrate of mercury, but not in the pernitrate.

1171. *Mercury and Nitric Acid.*—Nitric acid is rapidly decomposed by mercury; nitrous acid, and nitric oxide gases are evolved, and either a protonitrate or a pernitrate of mercury are obtained, according to the mode in which the solution is performed.

1172. *Protonitrate of Mercury* is best obtained by dissolving the metal in a cold and dilute acid, consisting of one part of acid and three of water; the metal should be added in small successive portions until the acid ceases to act upon it, and care should be taken to keep the whole cold. This solution deposits transparent crystals which appear to be modified octoëdra, and which consist of the protoxide of mercury combined with nitric acid. They are soluble without decomposition in cold water, and the solution affords black precipitates of protoxide. upon the addition of the alcalis.

1173. *Pernitrate of Mercury.*—When mercury is dissolved in hot and concentrated nitric acid, it becomes peroxidised, and furnishes prismatic crystals of the pernitrate. Their solution furnishes yellow or red precipitates of peroxide of mercury, upon the addition of potassa or soda, and ammonia forms a white precipitate which is a *triple nitrate of mercury and ammonia.*

When the precautions in forming the nitrates above described are not attended to, the solution usually contains a mixture of the two nitrates, and furnishes a precipitate with the alcalis, composed of both oxides. The pernitrate is most certainly formed by dissolving the red oxide in nitric acid.

1174. When hot water is poured upon pernitrate of mercury, a yellow insoluble powder separates from it, which is a *subpernitrate*, the *nitrous turpeth* of old writers; and a *super-pernitrate* remains in solution. It seems probable that the protonitrate is also capable of affording a sub and a super nitrate; but all these compounds have hitherto been but imperfectly investigated, and new researches are wanting to establish their nature and composition.

If the protonitrate and pernitrate be composed of one proportional of each of the oxides with one of acid and with two of acid, the following will be their component parts.

208	protoxide	216	peroxide
54	nitric acid	108	nitric acid
262	protonitrate of M.	324	pernitrate of M.

The subpernitrate has been analyzed by M. M. Braamcamp and Oliva, (*Thomson*, Vol. ii. p. 635), and they report its composition at

12	acid
88	peroxide
100	

If its composition in theory be admitted as 2 proportionals of peroxide = 432 + 1 proportional of nitric acid = 54, these numbers are not much at variance with the above experimental result, thus, as 88 : 12 : : 432 : 58.

1175. When these nitrates of mercury are exposed to heat gradually raised to dull redness, nitric acid is given off; and a brilliant red substance remains, consisting of peroxide of mercury with a small portion of adhering nitrate. This is used in pharmacy as an escharotic, and is called in the *London Pharmacopœia*, *hydrargyri nitrico-oxidum.*

In the manufacture of this compound at Apothecaries' Hall, 100 lbs. of mercury are boiled with 48 lbs. of nitric acid (specific gravity 1.48), and by proper evaporation and application of a dull red heat, 112 lbs. of the *hydrargyri nitrico-oxidum* are obtained.

1176. *Mercury and Sulphur.*—When one part of mercury is triturated for some time with three of sulphur, a black tasteless compound is obtained, which was called in old pharmacy *Ethiops Mineral;* it is, however, no longer retained in the *London Pharmacopœia.*

The same substance is more readily formed by pouring mercury into melted sulphur, the substances quickly combine, with such a rise of temperature as often produces inflammation.

1177. There is some difficulty in ascertaining how far these are definite compounds; when, however, sulphuretted hydrogen is passed through a dilute solution of nitrate of mercury, a black powder is thrown down, which appears to be a true sulphuret, and which, according to Guibourt, (*Annales de Chimie, et Phys.*, Tom. i.) consists of 100 mercury + 8.2 sulphur, numbers which nearly correspond to

1 proportional mercury = 200
1 ———— sulphur = 16

Sulphuret of mercury = 216

1178. When the black sulphuret is heated red hot in a flask, a portion of mercury evaporates, and a sublimate of a steel grey colour is obtained, which, when reduced to a fine powder, assumes a brilliant red colour, and is called *vermillion* or *cinnabar.* It is, in fact, a *bisulphuret of mercury,* and consists of

1 proportional of mercury = 200
2 ———— sulphur = 32

Bisulphuret of mercury = 232

1179. In the manufacture of cinnabar 8 parts of mercury are mixed in an iron pot with one of sulphur, and made to combine by a moderate heat, and constant stirring: this compound is then transferred to a glass subliming vessel, (on a small scale, a Florence flask answers perfectly), and heated to redness in a sand bath; a quantity of mercury and of sulphur evaporate, and a sublimate forms which is removed, and rubbed or levigated into a very fine powder.

1180. Cinnabar is not altered by exposure to air or moisture; when heated to dull redness in an open vessel, the sulphur forms sulphurous acid, and the mercury escapes in vapour. It is decomposed by distillation with fixed alcalis, lime, and baryta, and by several of the metals. When adulterated with red lead it is not entirely volatile.

1181. Cinnabar may be made in the humid way by long trituration of mercury and sulphur in solution of potassa.—NICHOLSON'S *Journal,* iv. to ii.

1182. *Native Cinnabar* is the principal ore of mercury: it occurs massive and crystallized in six-sided prisms, rhombs, and octoëdra. It is of various colours, sometimes appearing steel grey, at others bright red. It occurs in Hungary, France, and Spain, in Europe: in Siberia, and Japan, in Asia; and in considerable quantities in South America. The mines of Almaden, and of New Spain, are the most productive, and furnish fine cabinet specimens. Native mercury, and native amalgam of silver sometimes accompany it.

1183. *Hyposulphite of Mercury* appears not to exist: when a solution of a hyposulphite is poured into a very dilute solution of protonitrate of mercury it occasions a black precipitate.

1184. *Sulphite of Mercury* has not been examined.

1185. *Mercury and Sulphuric Acid.*—When mercury is boiled in its weight of sulphuric acid, sulphurous acid gas is evolved, a part of the metal is oxydized and dissolved, and a white deliquescent mass is obtained, which, washed with cold water, affords a very difficultly soluble white salt, which is a *protosulphate of mercury*. It requires 500 parts of water for its solution and crystallizes in prisms. According to Fourcroy (*Annales de Chimie*, x.) it consists of

12 sulphuric acid
83 protoxide of mercury
5 water.

According to theory, it should consist of one proportional of sulphuric acid + 1 of protoxide, or

40 sulphuric acid
208 protoxide of mercury

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248 sulphate of mercury.

The alcalis precipitate black oxide of mercury from this salt.

1186. If three parts of sulphuric acid be boiled to dryness with one of mercury, a white mass of *persulphate of mercury* is obtained; it is more soluble than the sulphate, and crystallizes in prisms. According to Braamcamp and Oliva, it is composed of

31.8 acid
63.8 peroxide
4.4 water

100.0

It should consist, according to theory, of 1 proportional of peroxide + 2 proportionals of acid.

1187. When hot water is poured upon persulphate of mercury, a yellow insoluble *subpersulphate* is formed, formerly called *Turpeth mineral*. It appears to consist of 1 proportional of peroxide + 1 of acid, or

216 peroxide of mercury
40 sulphuric acid

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256 subpersulphate of mercury.

A *bipersulphate* remains in solution.

1188. The solutions of persulphate of mercury furnish red precipitates with the fixed alcalis, and white with ammonia, the latter being a triple *sulphate of ammonia and mercury*.

1189. Sulphuretted hydrogen produces a black precipitate in solutions of mercury when added in excess, and which appears to be a sulphuret of mercury.

1190. *Phosphuret of Mercury* may be formed by heating phosphorus with oxide of mercury. It is a sectile solid of a bluish black colour.

1191. Neither the *Hypoposphite* nor *Phosphite of Mercury* have been examined.

1192. *Mercury and Phosphoric Acid.*—When phosphate of soda is added either to nitrate or pernitrate of mercury, a white precipitate is formed. There is probably a *protophosphate* and a *perphosphate*. The latter is soluble in excess of acid.

1193. *Mercury and Carbonic Acid.*—Alcaline carbonates produce buff-coloured precipitates in solutions of both oxides of mercury. These are probably the *protocarbonate* and the *percarbonate*.

1194. *Mercury and Cyanogen.*—By boiling one part of finely powdered red oxide of mercury with two of Prussian Blue, in eight parts of water, a solution is obtained, which, if filtered while hot, deposits, on cooling, yellowish white crystals in the form of quadrangular prisms, of a metallic taste and very poisonous, consisting, according to Gay-Lussac, of 80 mercury + 20 cyanogen. They are, therefore, a *cyanuret of mercury*, and probably contain 1 proportional of mercury = 200 + 2 of cyanogen = 48.8.

1195. Cyanuret of mercury is decomposed by heat, as in the process for obtaining cyanogen; and if distilled with muriatic acid, hydrocyanic acid and chloride of mercury are formed. It also is decomposed by hydriodic acid and by sulphuretted hydrogen, an iodide and a sulphuret of mercury, and hydrocyanic acid, being formed. The alcalis do not act upon this cyanuret.

1196. Cyanuret of mercury is also formed by boiling peroxide of mercury in solution of ferrocyanate of potassa; a portion of mercury and of peroxide of iron are at the same time deposited, whence it appears that the oxygen of the mercurial oxide is partly transferred to the iron, and partly to the hydrogen of the ferrocyanic acid.

1197. Cyanuret of mercury boiled in water with peroxide of mercury produces a compound which forms small granular crystals consisting of cyanuret and oxide of mercury; hence in making the cyanuret by the above process (1194) excess of mercurial oxide should be avoided.

1198. *Borate of Mercury*, obtained by adding borate of soda to nitrate of mercury, is a yellow insoluble powder.

1199. *Arseniates of Mercury.*—Arsenic acid occasions a pale yellow precipitate in solution of protonitrate of mercury, and a yellowish white precipitate in solution of the pernitrate. Arsenious acid produces white precipitates in both solutions.

1200. Molybdic acid occasions a white precipitate in solution of nitrate of mercury.

1201. *Chromate of Mercury.*—Chromate of potassa throws down an orange-coloured precipitate from the solutions of nitrate and pernitrate of mercury.

1202. *Tungstate of Mercury.*—Not examined.

1203. The soluble salts of mercury furnish whitish precipitates with ferrocyanate of potassa, and black with sulphuretted hydrogen. A plate of copper, immersed into their solutions, occasions the separation of metallic mercury.

The insoluble mercurial salts are mostly entirely volatilized at a red heat; if distilled with charcoal, they afford metallic mercury.

1204. Mercury combines with most of the other metals, and forms a class of compounds which have been called *amalgams*. These are generally brittle or soft. One part of potassium with 70 of mercury produce a hard brittle compound. If mercury be added to the liquid alloy of potassium and sodium (606), an instant solidification ensues, and heat enough to inflame the latter metals is evolved. The use of an amalgam of zinc and mercury has already been adverted to for the excitation of electrical machines. (108.) The amalgams of gold and silver are employed in gilding and plating.

An amalgam of 2 parts of mercury, 1 of bismuth, and 1 of lead, is fluid, and when kept for some time, deposits cubic crystals of bismuth.

Amalgam of copper may be made as follows: To a hot solution of sulphate of copper, add a little muriatic acid, and a few sticks of zinc, and boil the mixture for about a minute: by this means the copper will be precipitated in a metallic state, and in a finely divided spongy form: take out the zinc, pour off the liquor, wash the copper with hot water, and pour upon it a little dilute nitrate of mercury, which will instantly cover every particle of copper with a coating of mercury: then add mercury to the amount of two or three times the weight of the copper, and a slight trituration will combine them so far that the completion of the process may be effected by heating the mixture for a few minutes in a crucible.—Aikin's *Dictionary*, Art. *Mercury*, p. 92.

1205. When mercury is negatively electrized in a solution of ammonia, or when an amalgam of potassium and mercury is placed upon moistened muriate of ammonia, the metal increases in volume, and becomes of the consistency of butter, an appearance which has sometimes been called the *metallization of ammonia*. The compound appears only to contain ammonia and mercury, though its real nature has not been satisfactorily ascertained. It has suggested some hypotheses concerning the nature of ammonia and the metals, which are not worth recording.

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Section XXX. *Osmium*.

1206. Osmium, and the metals described in the three following sections, are contained in the ore of platinum. This ore is digested in nitro-muriatic acid, by which the greater portion is dissolved, and there remains a black powder, which, when fused with potassa and washed, furnishes a yellow alcaline solution of oxide of osmium. Saturate the alcali with sulphuric acid, pour the mixture into a retort, and distil. A colourless solution of the *oxide of osmium* passes into the receiver; it has a sweetish taste and a very peculiar smell, somewhat like that of new bread. When mercury is shaken with this solution it becomes an amalgam, which is decomposed by distillation, and pure osmium remains.

1207. Osmium has a dark grey colour, and is not volatile when heated in close vessels: but heated in the air it absorbs oxygen, and forms a volatile oxide. It has not been fused.

1208. The leading characters of osmium are its insolubility in the acids, its ready solubility in potassa, the facility with which it is oxidized, the singular smell of its oxide, its great volatility, and the purple or blue colour produced in its solution by tincture of galls. The other compounds have scarcely been examined.

SECTION XXXI. *Iridium.*

1209. THE black powder mentioned in the last section contains iridium, which resists the action of potassa, and consequently remains after the separation of osmium. A solution of its oxide may be procured by digesting it in muriatic acid, which first becomes blue, then olive-green, and lastly, red. By alternate treatment with potassa and muriatic acid, the whole of the black powder will be dissolved. By evaporating the muriatic solution to dryness, dissolving the dry mass in water, and evaporating a second time, octoëdral crystals of muriate of iridium are obtained.

1210. Iridium is obtained by immersing a plate of zinc into a solution of the muriate, or by violently heating the octoëdral crystals. It is of a whitish colour, and, according to Mr. Children, who succeeded in fusing it by means of his large Voltaic apparatus, its specific gravity is above 18. Its most marked character is extremely difficult solubility in the acids.

1211. In crude platinum Dr. Wollaston discovered some flat white grains which resisted the action of the acids, and which he ascertained to consist of *a native alloy of osmium and iridium.*

1212. Osmium and iridium were discovered by Mr. Tennant in 1803. The name of the former is derived from the peculiar smell of its oxide; that of the latter, from the variety of colours exhibited by its solution.—*Phil. Trans.*, 1804.

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SECTION XXXII. *Rhodium.*

1213. RHODIUM and Palladium were discovered by Dr. Wollaston in 1803. These, like the two last described metals, exist in the ore of platinum, from which rhodium may be obtained by the following process: Digest crude platinum in a small quantity of nitro-muriatic acid, filter the saturated solution, and pour it into a solution of sal ammoniac, by which the greater proportion of the platinum is precipitated. Decant the clear liquor and immerse a plate of zinc, which becomes coated with a black powder. Separate this and digest it in dilute nitric acid, by which a little copper and lead are taken up. Then wash and digest in dilute nitro-muriatic acid, to which add some common salt, evaporate to dryness, and wash the dry mass repeatedly with alcohol. A deep red substance remains, which, when dissolved in water, furnishes a black precipitate upon the immersion of a plate of zinc. This strongly heated with borax, assumes a white metallic lustre, and is rhodium.

1214. Rhodium is very difficult of fusion; its specific gravity is 10.6. When an alloy of lead and rhodium is digested in nitro-muriatic acid, it is dissolved, and by evaporation a red compound is obtained, from which muriate of rhodium may be separated by water, or more perfectly by alcohol. The rose-colour of this compound suggested the name which has been applied to the metal.

1215. Rhodium forms malleable *alloys* with the malleable metals, several of which have been examined by Dr. Wollaston.—*Phil. Trans.*, 1804. THOMSON's *System*, Vols. i. and ii.

With steel, rhodium forms an alloy, which probably would be very useful in the arts, were it not for the scarcity of the latter metal. 1 to 2 *per. cent.* of rhodium gives steel great hardness, and yet there is sufficient tenacity to prevent cracking either in forging or hammering. —*Quarterly Journal*, ix. 328.

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SECTION XXXIII. *Palladium.*

1216. PALLADIUM is most easily obtained by the following process, (WOLLASTON, *Phil. Trans.*, 1805.) Digest the ore of platinum in nitro-muriatic acid, neutralize the redundant acid by soda, throw down the platinum by muriate of ammonia, and filter. To the filtered liquor add a solution of cyanuret of mercury (1194); a yellow flocculent precipitate is soon deposited which yields palladium on exposure to heat.

1217. Palladium is of a dull white colour, malleable and ductile. Its specific gravity is about 11. It is hard. It fuses at a temperature above that required for the fusion of gold.

1218. Dr. Wollaston has ascertained the existence of *native palladium* in the ore of platinum. It is in small fibrous grains.

1219. Muriatic acid boiled upon palladium acquires a fine red colour. Sulphuric acid becomes blue. Nitric acid readily dissolves it; but its best solvent is the nitro-muriatic, which forms a fine red solution. The alcalis throw down an orange-coloured precipitate from these solutions, sparingly soluble in the alcalis. Ferrocyanate of potassa gives an olive-green precipitate; and sulphuretted hydrogen, one of a dark brown colour.

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SECTION XXXIV. *Silver.*

1220. SILVER is found native, and in a variety of combinations.

Native Silver has the general characters of the pure metal. It occurs in masses; aborescent; capillary; and, sometimes, crystallized in cubes and octoëdra. It is seldom pure, but contains small portions of other metals, which affect its colour and ductility. It is chiefly found in primitive countries. In Peru and Mexico are the richest known mines of native silver. The mines of Saxony, Bohemia, and Swabia, and those of Kongsberg in Norway, are the richest in Europe. It has been found in Cornwall and Devonshire.

Mode of obtaining.

1221. Pure silver may be procured by dissolving the standard silver of commerce in pure nitric acid, diluted with an equal measure of water. Immerse a plate of clean copper into the solution, which soon occasions a precipitate of metallic silver; collect it upon a filter; wash it with solution of ammonia, and then with water, and fuse it into a button.

It may also be procured by adding to the above solution of standard silver a solution of common salt; collect, wash, and dry the precipitate, and fuse it with its weight of carbonate of potassa. A button of the pure metal is thus obtained.

1222. Silver has a pure white colour, and considerable brilliancy. Characters. Its specific gravity is 10.5. It is so malleable and ductile, that it may be extended into leaves not exceeding a ten-thousandth of an inch in thickness, and drawn into wire finer than a human hair.

1223. Silver melts at a bright red heat, and when in fusion appears extremely brilliant. It resists the action of air at high temperatures for a long time, and does not oxidize; the *tarnish* of silver is occasioned by sulphureous vapours; it takes place very slowly upon the pure metal, but more rapidly upon the alloy with copper used for plate, and was found by Proust to consist of sulphuret of silver. Pure water has no effect upon the metal; but if the water contain vegetable or animal matter, it often slightly blackens its surface in consequence of the presence of sulphur. If an electric explosion be passed through fine silver wire, it burns into a black powder, which is an oxide of silver. In the Voltaic circle it burns with a fine green light, and throws off abundant fumes of oxide. Exposed to an intense white heat, it boils and evaporates. If suddenly cooled, it crystallizes during congelation, often shooting out like a cauliflower, and throwing small particles of the metal out of the crucible.

1224. Silver is not unfrequently obtained in considerable quantities from argentiferous sulphuret of lead, which is reduced in the usual way and then *cupelled;* the oxide of lead thus procured is afterwards reduced by charcoal.

Some of the silver ores, especially the sulphurets, are reduced by amalgamation. These ores, when washed and ground, are mixed with a portion of common salt and roasted; it is then powdered and mixed by agitation with mercury, and the amalgam thus formed is distilled.

The old process of *eliquation* is now scarcely used: it consisted in fusing alloys of copper and silver with lead; this triple alloy was cast into round masses, which were set in a proper furnace upon an inclined plane of iron with a small channel grooved out, and heated red-hot, during which the lead melted out, and in consequence of its attraction for silver, carried that metal with it, the copper being left behind in a reddish black spongy mass.—AIKIN'S *Dictionary*, Art. SILVER.

1225. *Oxide of Silver* may be obtained by adding lime-water to the solution of nitrate of silver, and washing the precipitate. It is of a dark olive colour, tasteless, insoluble in water, and when gently heated, is reduced to the metallic state.

The composition of oxide of silver has been very variously given, probably from the difficulty of obtaining it of similar purity. If its composition be inferred from the chloride, or from the sulphuret, we obtain the number 109.3 as the representative of silver, and the oxide will consist of

109.3 silver
8 oxygen

117.3 oxide of silver

By a direct experiment upon the oxide of silver, precipitated by potassa from the nitrate, it is found that 40 grains gave 7.9 cubical inches of oxygen, and 36.4 grains of silver remained; the 7.9 cubic inches would weigh 2.686 grains, and

Oxygen.		Silver.		Oxygen.		Silver.
2.686	:	36.4	::	8	:	108.4

I have preferred the number 109.3 as being deduced from the chloride, which is a more uniform compound than the oxide.

1226. Mr. Faraday has rendered it probable that there is another combination of silver and oxygen, containing a smaller proportion of oxygen than the above, but it is not capable of combining with the acids.

Fulminating silver.

1227. Oxide of silver readily dissolves in ammonia, and by particular management, a *fulminating silver*, composed of the oxide combined with ammonia, may be obtained. It was discovered by Berthollet, (*Annales de Chimie*, Tom. i.) The best process for obtaining it is to pour a small quantity of liquid ammonia upon the oxide; a portion is dissolved, and a black powder remains, which is the detonating compound. It explodes when gently heated; nitrogen and water are instantaneously evolved, and the silver is reduced. The oxide of silver should be perfectly pure and thoroughly edulcorated, and the ammonia quite free from carbonic acid. It should only be prepared in small quantities, and handled with the greatest caution, many accidents having arisen from its careless management. It sometimes explodes while still wet.

1228. *Silver and Chlorine.—Chloride of Silver.*—This compound is easily procured by adding a solution of chlorine, of muriatic acid, or of common salt, to a solution of nitrate of silver: it falls in the form of a heavy insoluble tasteless powder, of a white colour, but which, by exposure to light, becomes brown, and ultimately black. When dry chloride of silver is heated to dull redness in a silver crucible it does not lose weight, but fuses; and, on cooling, concretes into a grey semi-transparent substance, which has been called *horn silver*, or *luna cornea*. If slowly cooled, Proust has remarked that it has a tendency to octoëdral crystallization. Heated to a bright red or white heat in an open vessel, it volatilizes in dense white fumes.

1229. If fused with twice its weight of potassa or soda, chloride of silver is decomposed, and a globule of metallic silver is obtained. It is also rapidly decomposed by tin and zinc. Triturated with zinc filings and moistened, the heat produced is so considerable as to fuse the resulting alloy of zinc and silver.—FARADAY, *Quarterly Journal of Science and Arts*, viii. 374.

1230. Chloride of silver is very soluble in ammonia, a circumstance by which it is usefully distinguished from some other chlorides, which, like it, are white, and formed by precipitation. We should be cautious in applying heat to the ammoniacal solution, as it sometimes forms a precipitate of fulminating silver. The ammoniacal solution furnishes crystals, which, when exposed to air, or put into water, lose their transparency, ammonia is evolved, and they crumble into chloride of silver. The fused chloride, exposed to ammoniacal gas, absorbs a considerable portion, which is given off by heat. If the dry chloride, thus saturated with ammonia, be thrown into chlorine, the ammonia spontaneously inflames. (FARADAY, *Journal of Science and Arts*, Vol. v., p. 75.) Chloride of silver is soluble in and decomposed by all the liquid hyposulphites.

1231. As chloride of silver is insoluble in water, and very readily formed, it is often employed in analysis, as a means of ascertaining the proportion of chlorine present in various compounds. In these cases some excess of the precipitant should be used, and the precipitate allowed to subside previous to separating it upon the filter; if the supernatant liquor become perfectly clear, the whole of the silver has fallen; if it remain opalescent, a portion is probably still retained. The chloride in these cases should be perfectly dried in a silver crucible, up to incipient fusion.

1232. The following are three of the best analyses of chloride of silver, and their close correspondence is no small test of their accuracy.

	Marcet.	Gay-Lussac.	John Davy.
Silver	75.47	75.25	75.5
Chlorine	24.53	24.75	24.5
	100.00	100.00	100.0

The mean composition deduced from these experiments may be called

Silver	*75.4*
Chlorine	*24.6*
	100.

And we may accordingly, without material error, consider the chloride of silver as composed of

1 prop of silver = 109.3
1 ——— chlorine = 36.
145.3 chloride of silver.*

1233. *Native Chloride of Silver* has been found in most of the silver mines; it occurs massive and crystallized in small cubes.

1234. *Chlorate of Silver* is formed by digesting oxide of silver in chloric acid: it forms small rhombic crystals, which by the action of chlorine are converted into chloride of silver.

1235. Muriatic acid has no action upon a piece of clean silver, unless boiled with it for a long time, when a slight crust of chloride forms upon it. A beautiful experiment, illustrating the influence of electricity on chemical action, consists in attaching a slip of silver to one of zinc, and putting the double bar into dilute muriatic acid; the silver

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* Mr. Brande not having in this place, no more than in several others, assigned any authority for the determination he makes of the representative numbers, we must suppose it to rest on experiments of his own, though this is not said, and we therefore adhere to his proportions, only making here the due correction for chlorine.

$$\text{Thus as, } 33.5 : 102.5 :: 36 : 109.3 \left\{ \begin{array}{l} \text{33.5 and 102.5 are the} \\ \text{Num. of Brande.} \end{array} \right.$$

But we must observe, that in every case where the representative number is fractional, or an uneven integer, the accuracy of it is doubtful; for on a review of the multiples of hydrogen they appear to be even integers.

instantly acquires a crust of chloride in consequence of the negative energy imparted to it by the zinc, the latter metal being rapidly dissolved.

1236. *Iodide of Silver* is precipitated upon adding hydriodic acid to a solution of nitrate of silver. It is of a greenish yellow colour, insoluble, and decomposed when heated with potassa. It is particularly characterized by insolubility in ammonia.

1237. *Iodate of Silver* is precipitated in the form of a white powder by adding iodic acid or iodate of potassa to a solution of nitrate of silver. It is very soluble in ammonia.

1238. *Nitrate of Silver.*—Nitric acid, diluted with three parts of water, readily dissolves silver, with the disengagement of nitric oxide gas. If the acid contain the least portion of muriatic, the solution will be turbid, and deposit a white powder; and if the silver contain copper, it will have a permanent greenish hue; or if gold, that metal will remain undissolved in the form of a black powder.

The solution should be perfectly clear and colourless; it is caustic, and tinges animal substances of a deep yellow, which, by exposure to light, becomes a deep purple, or black stain, and is indelible, or peels off with the cuticle: it consists of reduced silver. It may be obtained in white crystals, in the form of four and six-sided tables, of a bitter and metallic taste, and soluble in about their own weight of water at 60°. It blackens when exposed to light, and when thus acted upon, is no longer perfectly soluble in water, owing to the separation of a portion of metallic silver.

1239. When heated in a silver crucible it fuses, and if cast into small cylinders, forms the *lapis infernalis*, or *lunar caustic* of pharmacy; the *argenti nitras* of the *Pharmacopœia*. In forming this preparation, care should be taken not to overheat the salt, and the moulds should be warmed. Exposed to a red heat, the acid is partly evolved and partly decomposed, and metallie silver obtained.

1240. Sulphur, phosphorus, charcoal, hydrogen, and several of the metals, decompose this nitrate. A few grains mixed with a little sulphur, and struck upon an anvil with a heavy hammer, produce a detonation; phosphorus occasions a violent explosion when about half a grain of it is placed upon a crystal of the nitrate, upon an anvil, and struck sharply with a hammer; and if heated with charcoal, it deflagrates, and the metal is reduced.

If a piece of silk dipped into a solution of nitrate of silver be exposed while moist to a current of hydrogen gas, it is first blackened, and afterwards becomes iridescent from the reduction of portions of the metal.—Mrs. Fulhame's *Essay on Combustion.*

A stick of phosphorus, introduced into a solution of nitrate of silver, soon becomes beautifully incrusted with the metal, which separates upon it in arborescent crystals. A plate of copper occasions a brilliant precipitation of silver, and the copper is oxidized and dissolved by the acid.

1241. Mercury introduced into the solution of nitrate of silver, causes a beautiful crystalline deposit of silver, called the *arbor Dianæ*: it was first remarked by Lemery. To obtain this crystallization in its most perfect state, the solution should contain a little mercury, and the mercury put into it should be alloyed with a little silver. Baumé directs an amalgam of one part of silver with seven of mercury, of which

Arbor dianæ.

a small piece is to be introduced into a solution composed of six drachms of saturated nitrate of silver and four drachms of a similar solution of mercury diluted with five ounces of distilled water; a small flask or matrass should be used for the experiment, kept perfectly at rest: in a few minutes small filaments of silver darken the surface of the amalgam, and in about eight and forty hours the whole has separated in a shrub-like form. The principal use of the addition of mercury to the solution, and of silver to the precipitating mercury, is to give a degree of tenacity to the arborescent deposit of crystals, which prevents their falling to the bottom of the flask.

1242. The alcaline metallic oxides decompose this salt of silver: it is also decomposed by muriatic, sulphuric, phosphoric, and boracic acid. The protosulphate of iron throws down metallic silver when added to a solution of the nitrate: protomuriate of tin forms a grey precipitate consisting of peroxide of tin and oxide of silver.

1243. Ammonia added to solution of nitrate of silver occasions a precipitate soluble in excess of the alcali.

1244. Nitrate of silver is of much use, as a test for chlorine, muriatic acid, and their compounds. It is employed for writing upon linen under the name of *indelible* or *marking ink*, and is an ingredient in many of the liquids which are sold for the purpose of changing the colour of hair. It is used in medicine and surgery.

1245. *Nitrite of Silver* is obtained, according to Proust, by long digestion of powdered silver in nitric acid already saturated with the metal. It is more soluble than the nitrate, and difficultly crystallizable. It appears not improbable that this salt may contain the suboxide noticed by Mr. Faraday. (1226.)

1246. *Sulphuret of Silver.*—Silver readily combines with sulphur, and produces a grey crystallizable compound, considerably more fusible than silver. It is this which forms the *tarnish* upon silver plate. (1223) It consists of 1 proportional of each of its components.

Silver . .	109.3
Sulphur.	16.
	125.3 sulphuret of silver.

1247. Sulphuretted hydrogen and hydrosulphuret of ammonia occasion a copious black precipitate of sulphuret of silver when added to solutions of the metal; a portion of the silver is frequently at the same time reduced to the metallic state.

1248. *Native Sulphuret of Silver*, or *vitreous silver ore*, is found in various forms, and when crystallized, is in cubes, octoëdra, and dodecaëdra. It is soft and sectile. The finest specimens are from Siberia.

1249. A triple combination of silver and antimony with sulphur, constitutes the *red* or *ruby silver ore;* it is found massive and crystallized in hexaëdral prisms. It consists of about 70 parts of sulphuret of silver, and 30 sulphuret of antimony. It occurs in all the silver mines, and is sometimes accompanied by the *brittle sulphuret of silver*, or *silver glance.*

1250. *Hyposulphite of Silver* has been examined by Mr. Herschel in his able paper on the hyposulphurous acid (*Edin. Phil. Journal*, i. 26.) It is formed by dropping a weak solution of nitrate of silver into a very dilute solution of hyposulphite of soda; a white cloud is at first produced, which re-dissolves on agitation; on adding more of the precipitant, the cloud re-appears and aggregates into a grey precipitate, which appears to consist of hyposulphite of silver; the supernatant liquor tastes intensely sweet, which is remarkable considering the disgusting bitterness both of the nitrate and of the hyposulphite, and shows, says Mr. Herschel, "how little we know of the way in which bodies affect the organs of taste. Sweetness and bitterness, like acidity, seem to depend upon no particular principle, but to be regulated by the state of combination in which the same principles exist at different times."

Hyposulphite of silver is also produced when chloride of silver is dissolved in any of the hyposulphites; the solution is intensely sweet without any metallic flavour.

1251. *Hyposulphite of Potassa and Silver* is formed when liquid potassa is dropped into the solution of chloride of silver in hyposulphite of soda; it separates in the form of a copious precipitate, which, when washed and dried, is found to consist of small grey pearly scales: they are difficultly soluble in water; of a very sweet taste; and heated before the blow-pipe afford a bead of silver.

1252. *Sulphite of Silver* is obtained in crystalline grains by digesting oxide of silver in sulphurous acid.

1253. *Sulphate of Silver* is deposited when sulphate of soda is mixed with nitrate of silver. It is also formed by boiling silver in sulphuric acid. It requires about 90 parts of water at 60° for its solution; in boiling water it is more soluble and is deposited, as the solution cools, in small prismatic crystals: it is decomposed at a red heat. It consists of

1 proportional of oxide of silver = 117.3
1 ——————— sulphuric acid = 40

157.3 sulphate of silver.

1254. A compound acid, which may be called *nitro-sulphuric*, consisting of one part of nitre dissolved in about ten of sulphuric acid, dissolves silver at a temperature below 200°, and the solution admits of moderate dilution before sulphate of silver separates from it. This acid scarcely acts upon copper, lead, or iron, unless diluted with water; it is, therefore, useful in separating the silver from old plated articles: the precious metal may afterwards be separated either in the form of chloride, by adding common salt; or by diluting the acid and continuing the immersion of the pieces of copper which have lost their silvering, and which will now dissolve in the diluted acid and occasion the precipitation of metallic silver.—KEIR, *Phil. Trans.*, lxxx.

1255. *Phosphuret of Silver* is a white brittle compound.

1256. Neither *Hypophosphite* nor *Phosphite of Silver* have been examined.

1257. *Phosphate of Silver* is formed by dropping a solution of phosphate of soda into nitrate of silver. It is of a yellow colour, and consists, according to Berzelius, (*Annales de Chimie, et Physique*, Tom. ii.) of

83 oxide of silver
17 phosphoric acid

100

so that it may be considered as a compound of 1 proportional of oxide of silver = 117.3 + 1 proportional of phosphoric acid = 28.

1258. *Carbonate of Silver* is precipitated in the form of a white insoluble powder, by adding carbonate of potassa to nitrate of silver. It blackens by exposure to light. It consists of

1 proportional of carbonic acid = 22
1 ———— oxide of silver = 117.3

Carbonate of silver = 139.3

1259. Carbonate of ammonia only throws down a portion of the silver from the nitrate, and forms a triple *ammonio-carbonate of silver*.

1260. *Borate of Silver* is thrown down from the nitrate of silver in the form of white powder, by adding solution of borate of soda.

1261. Hydrocyanic acid and hydrocyanate of potassa cause a white precipitate in solutions of silver, which appears to be a cyanuret of silver, and which, when heated, gives out cyanogen.

1262. *Arsenite of Silver* is precipitated in the form of a white powder, soon becoming yellow and brown, by the addition of solution of arsenious acid to nitrate of silver.

1263. *Arseniate of Silver* is thrown down from nitrate of silver by arsenic acid, of a reddish brown colour.

1264. *Molybdate of Silver* has not been examined.

1265. *Chromate of Silver* is precipitated of a crimson colour by adding chromate of soda to nitrate of silver. It soon loses its brilliant tint and becomes brown.

1266. *Tungstate of Silver*—not examined.

1267. The soluble salts of silver are recognised by furnishing a white precipitate with muriatic acid, which blackens by exposure to light, and which is readily soluble in ammonia ; and by affording metallic silver upon the immersion of a plate of copper. The salts insoluble in water are soluble in liquid ammonia, and when heated on charcoal before the blow-pipe they afford a globule of silver.

1268. *Alloys of Silver.*—The compounds of this metal with potassium, sodium, and manganese, have not been examined. It unites difficultly with iron.

1269. When silver and steel are fused together, an alloy is formed, which appears perfect while in fusion, but globules of silver exude from it on cooling, which shows the weak attraction of the metals. At a very high temperature the greater part of the silver evaporates, but a portion equal to about 1 in 500 remains, forming a perfect alloy, admirably adapted to the formation of cutting instruments.—STODART and FARADAY, on the Alloys of Steel. *Quarterly Journal*, ix.

1270. Silver readily combines with zinc and tin, forming brittle alloys. The alloy of silver with copper is of the most importance, as it constitutes plate and coin By the addition of a small proportion of copper to silver, the metal is rendered harder and more sonorous, while its colour is scarcely impaired.

The *standard silver* of this country consists of $11\frac{2}{20}$ pure silver and $\frac{18}{20}$copper. A pound troy, therefore is composed of 11 oz. 2 dwts. pure silver, and 18 dwts. of copper, and it is coined into 66 shillings. With lead the alloy is grey and brittle, as also with antimony, bismuth, cobalt, and arsenic.

1271. Amalgam of silver is sometimes employed for *plating*; it is applied to the surface of copper, and the mercury being evaporated by heat, the remaining silver is burnished. The better kind of plating, however, is performed by the application of a plate of silver to the surface of the copper, which is afterwards beaten or drawn out.

Silvering for dials.

1272. A mixture of chloride of silver, chalk, and pearlash, is employed for silvering brass: the metal is rendered very clean, and the above mixture, moistened with water, rubbed upon its surface. In this way thermometer scales and clock dials are usually silvered.

1273. The analysis of alloyed silver is a very important process, and in continual practice by refiners and assayers. It may be performed in the humid way by dissolving the alloy in nitric acid, precipitating with muriatic acid, and either reducing the chloride by potassa in the way above described (1229), or estimating the quantity of silver which it contains. The usual method, however, which is employed at the mint, and by the refiners, is *cupellation*.

1274. Of the useful metals, there are three only which are capable of resisting the action of air at high temperatures; these are silver, gold, and platinum; the others, under the same circumstances, become oxidized; it might, therefore, be supposed, that an alloy, containing one or more of the former metals, would suffer decomposition by mere exposure to heat and air, and that the oxidable metal would burn away. This, however, is not the case; for if the proportion of the latter be small, it is protected, as it were, by the former; or, in other cases, a film of oxide coats the fused globule, and prevents the further action of the air. These difficulties are overcome by adding to the alloy some highly oxidable metal, the oxide of which is fusible. Lead is the metal usually selected for this purpose, though bismuth will also answer. Supposing, therefore, that an alloy of silver and copper is to be *assayed*, or analyzed by cupellation: the following is the mode of proceeding.

Assaying.

A clean piece of the metal, weighing about 30 grains, is laminated, and accurately weighed in a very sensible balance. It is then wrapped up in the requisite quantity of sheet lead, (pure and reduced from litharge,) and placed upon a small *cupel*, or shallow crucible, made of bone earth, which has been previously heated. The whole is then placed under the muffle, heated to bright redness; the metals melt, and by the action of the air which plays over the hot surface, the lead and copper are oxidized and absorbed by the cupel, and a button of pure silver ultimately remains, the completion of the process being judged of by the cessation of the oxidation and motion upon the surface of the globule, and by the very brilliant appearance assumed by the silver when the oxidation of its alloy ceases. The button of pure metal is then suffered to cool gradually, and its loss of weight will be equivalent to the weight of the alloy, which has been separated by oxidation.

To perform this process with accuracy, many precautions are requisite, and nothing but practice can teach these, so as to enable the operator to gain certain results. An excellent article upon the subject will be found in AIKIN's *Chemical Dictionary*, and in Mr. CHILDREN's *Translation of* THENARD *on Chemical Analysis*.

SECTION XXXV. *Gold.*

1275. GOLD occurs in nature in a metallic state, alloyed with a little silver or copper, and in this state is called *native gold*. Its colour is various shades of yellow; its forms are massive, ramose, and crystallized in cubes and octoëdra. The veins of gold are confined to primitive countries, but large quantities of this metal are collected in alluvial soils and in the beds of certain rivers, more especially those of the west coast of Africa, and of Peru, Brazil, and Mexico. In Europe, the streams of Hungary and Transylvania have afforded a respectable quantity of gold; it has been found also in the Rhine, the Rhone, and the Danube. Small quantities have been collected in Cornwall, and in the county of Wicklow in Ireland. History.

1276. Gold may be obtained pure by dissolving standard gold in nitro-muriatic acid, evaporating the solution to dryness, re-dissolving the dry mass in distilled water, filtering, and adding to it a solution of protosulphate of iron; a black powder falls, which, after having been washed with dilute muriatic acid and distilled water, affords on fusion a button of pure gold. Mode of obtaining.

1277. Gold is of a deep yellow colour. It melts at a bright red heat, and when in fusion appears of a brilliant green colour.

Gold is so malleable that it may be extended into leaves which do not exceed $\frac{1}{282000}$ of an inch in thickness. It is also very ductile. It shows no tendency to unite to oxygen when exposed to its action in a state of fusion; but if an electric discharge be passed through a very fine wire of gold, a purple powder is produced, which has been considered as an oxide. Characters.

1278. *Oxide of Gold* may be obtained by adding a solution of potassa to a solution of muriate of gold, and heating the mixture; the precipitate must be washed first with weak solution of potassa, and then with water, and dried at a temperature of 100°; if the heat exceed this, a portion of the oxide is reduced, and it is then only partially soluble in muriatic acid. If this be regarded as a protoxide, that is, as consisting of 1 proportional of gold + 1 of oxygen, then the number 103.4+7.5 : 97 : : 8 : 103.4 will represent gold, and this oxide will consist of 103.4 gold + 8 oxygen = 111.4*. It is, however, probable that the purple powder produced by the combustion of gold contains a portion of oxygen.

1279. *Chloride of Gold.*—When gold in a state of minute divison is heated in chlorine, a compound of a deep yellow colour results, which is said to consist of 103.4 gold + 36 chlorine. When acted upon by water, a *muriate of gold* is produced. Salts of gold.

1280. The action of *iodine* on gold has been examined by M. Pelletier, (*Quarterly Journal of Science and Arts*, x. 121.) When hydriodate of potassa is added to muriate of gold, it produces a very copious yellowish brown precipitate, insoluble in cold water, and easily decomposed by heat. It gave on analysis

Iodine	34
Gold	66

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*These numbers are deduced from Proust's experiments.—NICHOLSON'S *Journal*, Vol. xiv.

If this be considered a compound of 1 proportional gold and 1 of iodine, the number 242.6 must be adopted as the representative of gold, for 34 : 66 :: *125 : 242.6, a number so much at variance with that deduced from other experiments, as to show the necessity of further inquiries, before either be adopted.

1281. *Nitrate of Gold.*—The nitric acid has scarcely any action upon gold, but it readily dissolves the oxide, forming a yellow styptic deliquescent salt.

1282. The true solvents of gold are solution of chlorine and nitro-muriatic acid; the latter is usually employed, composed of two parts of muriatic and one of nitric acid. By evaporation, the saturated solution, which, however, is always acid, affords prismatic crystals of *muriate of gold.* This salt is very deliquescent; it is decomposed by heat, leaving a spungy mass of pure gold; a very minute portion of the metal also passes off with the muriatic acid.

1283. When potassa is added to the solution of muriate of gold, no precipitate occurs till heat is applied, when a reddish-yellow precipitate falls, which is peroxide of gold (1278); the whole of the metal, however, is not thrown down, a portion being retained so as to form a *triple muriate of gold and potassa,* which is very soluble and not decomposed by further excess of alcali: it is on this account that a very acid solution of muriate of gold will afford no precipitate whatever with potassa or soda, the triple salt formed being in that case sufficient to employ the whole of the oxide of gold. M. Pelletier has stated that potassa alone dissolves oxide of gold, and has called the compound *aurate of potassa.*

Triple muriate.

1284. When liquid ammonia is added to a concentrated solution of muriate of gold diluted with about three parts of water, a yellowish-brown precipitate is formed, which if collected upon a filter, washed with a little water, and carefully dried at the temperature of 212°, is *fulminating gold.* Bergman first showed that this compound consists of about five parts of peroxide of gold and one of ammonia: when heated to about 400°, it explodes violently, the gold is reduced, and nitrogen and water are evolved; hence it appears that the ammonia is decomposed, that its hydrogen uniting with the oxygen of the oxide forms water, and that the nitrogen is suddenly liberated. It explodes by friction with hard bodies, and by an electrical shock. If two or three grains be detonated upon a thin piece of platinum leaf, the metal is torn at the point of contact.

Fulminating gold.

1285. Muriate of gold is decomposed by phosphorus and charcoal, and by sulphurous acid: a piece of paper, moistened with it and exposed to light, also becomes purple in consequence of its decomposition.

1286. When solution of protosulphate of iron is added to muriate of gold the mixture instantly acquires a dingy green or brown tinge, and appears of a beautiful green if viewed by strong transmitted light: these appearances depend upon the presence of an infinite number of small particles of gold in the metallic state, its oxygen having been imparted to the salt of iron: they soon subside in the form of a brown powder, which may be collected upon a filter and fused into a button. This method of separating gold from its solution is often convenient in analytical operations.

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* The number representing iodine, and the only one that is odd: probably incorrect.

1287. Protomuriate of tin, added to muriate of gold, occasions an instant change of colour to a reddish brown or dirty purple: if a piece of tin foil be immersed in a dilute solution of the muriate of gold, the same purple powder is presently thrown down upon it: this powder is used in enamel painting, and for tinging glass of a fine red colour, under the name of *purple of Cassius:* it is a compound of peroxide of tin and oxide of gold, the latter metal appearing to be in a very low state of oxidizement, and yet soluble in muriatic acid: it is also soluble in ammonia, forming a deep purple liquor. It would appear from Proust's experiments to consist of about three parts oxide of tin, and one of oxide of gold.

1288. If a solution of muriate of gold be mixed with sulphuric ether it combines with the oxide, and an *ethereal solution of gold* is obtained. Polished steel dipped into this solution acquires a coat of gold, and it has hence been employed for gilding delicate cutting instruments. (See *Sulphuric Ether.*)

1289. *Sulphuret of Gold* is procured by passing sulphuretted hydrogen through an aqueous solution of muriate of gold. It is a black substance consisting probably of 103.4 gold + 32 sulphur.—OBERKAMPF, *Annales de Chimie*, Tom. lxxx.

1290. *Sulphate of Gold* is formed by digesting the oxide in dilute sulphuric acid, but the salt has not been examined.

1291. *Phosphuret of Gold* is obtained by heating gold leaf with phosphorus, in a tube deprived of air. It is a grey substance of a metallic lustre, and consists probably of 103.4 gold + 12 phosphorus.

1292. *Alloys of Gold.*—A very curious detail of an extended and accurate series of experiments upon the alloys of gold has been published in the *Philosophical Transactions* for 1803, by Mr. Hatchett: his experiments were generally made with 11 parts of gold and 1 of alloy; or 38 grains of alloy to the ounce of gold.

1293. The alloys of gold with potassium, sodium, and manganese, have not been examined. With iron the alloy is malleable and ductile, and harder than gold, its colour dull white, and its specific gravity 16.885. The metals expand by union, so that supposing their bulk before combination to have been 1000, after combination it is 1014.7.

1294. With zinc the compound is brittle and brass-coloured. Specific gravity 16.937. The metals contract a little in uniting, the original bulk being 1000, that of the alloy is 997. The brittleness continued when the zinc was reduced to $\frac{1}{60}$ of the alloy. The fumes of zinc in a furnace containing fused gold, make it brittle.

1295. Tin formed a whitish alloy, brittle when thick, but flexible in thin pieces. Specific gravity 17.307. Bulk before fusion 1000; after fusion 981. So that there is considerable contraction. The old chemists called tin *diabolus metallorum*, from its property of rendering gold brittle; but Mr. Bingley's experiments quoted by Mr. Hatchett, show that $\frac{1}{60}$ of tin does not render gold brittle.

1296. The alloy of lead is very brittle when that metal only constitutes $\frac{1}{1920}$ of the alloy; even the fumes of lead destroy the ductility of gold. The specific gravity is 18.080; and 1000 parts become 1005. A very remarkable fact in respect to this alloy is, that its specific gravity diminishes, to a certain extent, as the proportion of lead diminishes, and is at its maximum when the lead amounts only to $\frac{1}{960}$th part, the quantity of gold remaining the same, and the deficiency being made up with copper. The following Table, drawn up by Mr. Hatchett, exhibits this remarkable fact:

METALS.	Grains.	Sp. Gravity of Alloy.	Bulk before Union.	Bulk after Union.	Expansion.
Gold . . . . . Lead	442 38	18.080	1000	1005	5
Gold . . . . . Copper . . . . Lead	442 19 10	17.765	1000	1005	6
Gold . . . . . Copper . . . . Lead	442 30 8	17.312	1000	1022	22
Gold . . . . . Copper . . . . Lead	442 34 4	17.032	1000	1035	35
Gold . . . . . Copper . . . . Lead	442 37.5 0.5	16.627	1000	1057	57
Gold . . . . . Copper . . . . Lead	442 37.75 0.75	17.039	1000	1031	31

1297. The alloy with nickel was of a brass colour and brittle. The specific gravity of the gold being 19.172, and of the nickel 7.8, that of the alloy was 17.068. An expansion had taken place, 1000 parts before fusion having become 1007.

1298. With cobalt the alloy was very brittle. Specific gravity 17.112. 1000 parts became 1001 after fusion.

1299. With bismuth the alloy was of a brass colour, very brittle, and of a specific gravity = 18.038. 1000 parts became 988 after fusion, so that the condensation was considerable. When the bismuth amounted only to $\frac{1}{1920}$th part, the alloy was still brittle, though the colour was nearly that of gold.

1300. With copper (standard gold) the alloy is perfectly ductile and malleable, but harder than pure gold, and resists wear better than any other alloy except that with silver. Its specific gravity is 17.157. Gold coin is an alloy of eleven parts of gold and one of copper; of this alloy, twenty troy pounds are coined into 934 sovereigns and one half sovereign; one pound formerly was coined into 44½ guineas; it now produces $46\frac{29}{40}$ sovereigns.

1301. Arsenic and antimony, when alloyed in very small proportions with gold, destroy its colour and render it quite brittle.

1302. The analysis of most of the alloys of gold is performed by cupellation. The triple alloy of gold, silver, and copper, may be analyzed by digesting it in nitric acid, which takes up the silver and copper, and leaves the gold in the form of a black powder, which may be fused into a button, and weighed. The silver may be thrown down in the state of chloride by solution of common salt, and the copper precipitated by iron.

1303. The assay of gold is more complicated than that of silver, in consequence of the high attraction which it has for copper, and which prevents its complete separation by mere cupellation. An alloy, therefore, of copper with gold, is combined with a certain quantity of silver, previous to cupellation; this is then cupelled with lead in the usual way, and the silver is afterwards separated by the action of nitric acid.

1304. The real quantity of gold or silver taken for an assay is very small; from 18 to 36 grains, for instance, for silver, and from 6 to 12 for gold; whatever the quantity may be it is called the *assay pound*. The silver assay pound is divided into 12 ounces, and each ounce into 20 penny-weights. The gold assay pound is subdivided into 24 carats, and each carat into 4 assay grains.—AIKIN's *Dictionary*. *Art.* ASSAY.

1305. Mercury and gold combine with great ease, and produce a white amalgam much used in gilding. For this purpose the amalgam is applied to the surface of the silver; the mercury is then driven off by heat, and the gold remains adhering to the silver, and is burnished. This process is called *water gilding*.

In gilding porcelain *gold powder* is generally employed, obtained by the decomposition of the muriate; it is applied with a pencil, and burnished after it has been exposed to the heat of the porcelain furnace.

Many curious facts relating to the properties of gold, and its uses in the arts, will be found in Dr. LEWIS's *Philosophical Commerce of the Arts*.

SECTION XXXVI. *Platinum.*

History.

1306. THIS metal is found in small grains in South America, confined to alluvial strata in New Granada. These grains, besides platinum, contain generally gold, iron, lead, palladium, rhodium, iridium, and osmium.

Mode of obtaining.

The pure metal may be obtained by dissolving crude platinum in nitro-muriatic acid, and precipitating by a solution of muriate of ammonia. This first precipitate is heated, dissolved in nitro-muriatic acid, and again precipitated as before. The second precipitate is heated white hot, and pure platinum remains. It is a white metal, extremely difficult of fusion, and unaltered by the joint action of heat and air. Its specific gravity is 21.5. It is very ductile, malleable, and tenacious.

1307. *Platinum and Oxygen.*—When nitrate of mercury is added to a dilute solution of muriate of platinum, a powder falls, which, when carefully heated, gives off calomel, and leaves a *black oxide of platinum*, composed, according to Mr. Cooper, of 100 platinum, + 4.5 oxygen.—*Journal of Science and the Arts*, Vol. iii.

Berzelius obtained an oxide of platinum by decomposing the muriate by sulphuric acid, and adding excess of potassa to the sulphate; a yellowish brown powder was obtained, which became nearly black on being dried, and consisted of 100 platinum + 16.4 oxygen. (THOMSON, Vol. i., p. 501.); but, according to Mr. Davy, the oxide, which is contained in the salts of platinum, consists of platinum 100, oxygen 11.8.

1308. *Chloride of Platinum* is obtained by evaporating the muriate and exposing it nearly to a red heat. Its colour is brown, and it is scarcely soluble in water. It gives off chlorine by a red heat. According to Mr. Edmund Davy, to whom we are principally indebted for our knowledge of the combinations of platinum, (*Phil. Mag*. Vol. xl.) it consists of 100 platinum + 37.9 chlorine.

1309. Nitro-muriatic acid is the readiest solvent of platinum. The solution affords crystals which are very deliquescent and acrid; they are a *muriate of platinum*. The solution of this muriate is distinguished from all other metallic solutions by affording a precipitate upon the addition of muriate of ammonia, which is an *ammonio-muriate of platinum*. Ferrocyanate of potassa affords no precipitate. The addition of potassa occasions a precipitate of a triple compound of the alcali and muriate. Sulphuretted hydrogen occasions a black precipitate. Ether separates the oxide of platinum in the same way as that of gold. Muriate of tin occasions a very characteristic red precipitate in very dilute solution of platinum.

1310. There are, according to Mr. E. Davy, three *sulphurets of platinum*. The first, formed by heating the finely-divided metal with sulphur; the second, by precipitating nitro-muriate of platinum by sulphuretted hydrogen; and the third, by heating 3 parts of the ammonio-muriate with 2 of sulphur.

1311. According to the same authority there are two phosphurets. The first, obtained by heating phosphorus with the metal; the second, by heating phosphorus with the ammonio-muriate of platinum.

1312. The salts of platinum have been but little examined. Proust and Davy have described a *sulphate*, obtained by acidifying the sulphur in the sulphuret by means of nitric acid. It is of a brown colour, and very soluble; and with soda, potassa, and ammonia, it forms triple salts.

Mr. E. Davy found that the precipitate by a slight excess of ammonia, when boiled in potassa, washed and dried, was a *fulminating platinum;* it explodes at about 420°, with a very loud report, and appears to be a compound of oxide of platinum, ammonia, and water.—*Phil. Trans.*, 1817.

1313. A very singular compound of platinum is described by Mr. E. Davy, in the *Philosophical Transactions* (1820, p. 108), obtained by mixing equal volumes of strong aqueous solution of the sulphate and of alcohol. The colour of the sulphate slowly disappears, and in some days a black substance subsides, which is washed and dried. It is also formed by boiling the sulphate and alcohol together for a few minutes. This substance is permanent in the air and insoluble in water. It detonates feebly when heated, and is not affected by chlorine, nor by nitric, sulphuric, and phosphoric acids; but it is slowly soluble in muriatic acid. Put into liquid ammonia it acquires fulminating properties, and plunged into the gas it becomes red hot: the same phænomenon is exhibited by exposing it to the vapour of alcohol, or by placing it upon a piece of paper moistened with that fluid: in these cases the platinum is reduced with the evolution of heat, and the ignition seems to depend upon the slow combustion of the vapour of the alcohol, as has been elsewhere shown. (191.) From Mr. Davy's analysis of this compound, it appears to contain 96.25 platinum, 0.12 oxygen, 0.0106 carbon 3.6194 nitric acid and water; the acid being derived from the mode of preparing the sulphate. (1312.)

1314. Experiments upon the composition of the various combinations of platinum are so entirely at variance with theory, that in the present state of our knowledge it is scarcely possible to deduce the number for platinum.

If the black oxide, described by Mr. Cooper, be considered as a protoxide, the number 177.7 will represent platinum, and the chloride (1308) will contain 1 proportional of platinum and 2 of chlorine. But the peroxide, the phosphurets, and the sulphurets, will not accord with this number.

1315. The alloys of platinum have not been applied to any useful purposes. By combining 7 parts of platinum with 16 of copper and 1 of zinc, Mr. Cooper obtained a mixture much resembling gold.—*Journal of Science and Arts*, Vol. iii., p. 119.

1316. Zinc, bismuth, tin, and arsenic, readily combine with platinum, and form fusible alloys. It also unites, though less readily, with copper, lead, and iron. It combines with gold, and unless there be great excess of the latter, the colour of the alloy resembles platinum.

1317. If a small piece of tin, zinc, or antimony, be rolled up in platinum leaf, and exposed to the jet of a blow-pipe, the two metals combine with such energy, when nearly white hot, as to produce a kind of explosion. Iron and steel also remarkably increase the fusibility of platinum.

1318. The alloys of steel and platinum have been examined by Stodart and Faraday. They combine in all proportions, but from 1 to 3 *per cent.* of platinum appears best adapted for cutting instruments. Equal weights of the two metals produce a fine hard and brilliant alloy of a specific gravity of 9.862; it appears well adapted for mirrors, for it takes a fine polish and does not tarnish. An alloy of 90 platinum and 20 steel has a specific gravity of 15.88.

1319. Platinum has the property of being united by welding, either one piece to another, or with iron, or steel. Wires of steel and platinum, when welded and polished, exhibit a curious and beautiful surface, especially when the steel parts are slightly acted upon by dilute acid. This welding property of platinum may be usefully applied in the arts; rings may be joined so as to form a chain, the durability of which must add to its value; and with a view to economy, platinum may be joined to iron or steel for many uses in the laboratory of the chemist.

SECTION XXXVII. *Silicium.*

1320. IT has been assumed that the earth silica consists of a metallic basis, united with oxygen, and that it contains 50 *per cent.* of each of its components; so that, if the earth be considered a deutoxide, it will consist of

16 silicium (1 proportional)
16 oxygen (2 proportionals)
—
32

This estimate of the composition of silica is deduced from the quantity of potassium which is required for its decomposition, but the subject requires farther elucidation.

1321. *Oxide of Silicium*, *Silica*, or *Siliceous Earth*, is a very abundant natural product. It exists pure in rock-crystal, and nearly pure in flint. It may be obtained by heating colourless rock-crystal to redness, quenching it in water, and reducing it to a fine powder; in this state it is silica almost perfectly pure. Fuse 1 part of this powder with three of potassa in a silver crucible. Dissolve the mass formed, in water, add slight excess of muriatic acid, and evaporate to dryness. Wash the dry mass in boiling distilled water upon a filter, and the white substance which remains is silica. This is the usual process, but the earth obtained by simply reducing the colourless rock-crystal to powder, is more pure; for I have never been able to separate the last portions of alcali from silica precipitated from potassa.

1322. Silica is white; its specific gravity 2.66. It fuses at a very high temperature. In its ordinary state it is insoluble in water; but it dissolves in very minute portions in that fluid, when recently precipitated in the form of gelatinous hydrate; and in the same state it dissolves sparingly in the acids. It readily unites with the fixed alcalis, and forms *glass;* or, if the alcali be in excess, a liquid solution of the earth may be obtained (*liquor silicum*), from which it is precipitated in the state of a *gelatinous hydrate* by acids. This alcaline solution, after having been kept for several years, has formed small crystals of silica. I have seen in it a deposit much like calcedony, and as hard.

1323. *Glass* is essentially a compound of silica with fixed alcali, a variety of other substances being occasionally added for particular purposes, among which oxide of lead is perhaps the most important. The silica used in the manufacture of glass is of various degrees of purity; fine white sand is generally employed in this country; flints, and the white quartz pebbles, abundant in some rivers, are also occasionally used. The alcali is either potassa or soda; purified pearlash being preferred for fine glass; while less pure substances, such as wood-ash, barilla, and kelp, are used for common glass, where the impurities contained in those alcalis are of no importance. The alcali is always in the state of carbonate, but it loses its carbonic acid during combination with the silica; the quantity employed is about half the weight of the silica, but there is some loss during the process, by evaporation.

A glass composed solely of silica and alcali requires a very high temperature for its perfect fusion, and is very difficult to work, so that various substances are added, with the intention of forming a more fusible, colourless, dense, and transparent compound; oxide of lead, in the form of litharge or minium, is very efficacious in this respect; it increases the fusibility of the compound, gives it greater tenaciousness when red hot, increases its refractive power, and enables it to bear sudden changes of temperature. It is a copious ingredient in the *London flint glass*, celebrated for its brilliancy when cut, and used for most optical purposes. But lead, though it confers these advantages, is productive of some evil; it renders the glass so soft as easily to scratch, and so fusible that it softens at a dull red heat, a quality which, though sometimes desirable, is often disadvantageous in its chemical applications. It is also very difficult to obtain a mass of glass containing lead, of equal density throughout; it is generally wavy, a defect especially felt in selecting the object-glasses of telescopes.

Boracic acid and borax form an admirable flux for glass-making, but the expense of those materials confines them almost entirely to the manufacture of artificial gems.

Black oxide of manganese has long been used in glass-making; it was formerly called *glass' soap*, a term implying its power of cleansing certain impurities, and especially the green tinge which is apt to arise from impure alcali; but if it be added at all in excess, it communicates a purple tinge, more or less intense according to its quantity. This purple hue is destroyed by charcoal, or by thrusting a billet of wood into the glass-pot, which causes a slight effervescence, and the colour disappears. There can be little doubt that the carbon acts by deoxidizing the manganese, for if a little nitre be added, the purple colour returns. Lime in very small quantities (8 or 10 parts of chalk to 100 of silica), is sometimes added to glass; it acts as a flux, but it endangers the transparency of the compound.

White arsenic is also used as a very cheap and powerful flux; and nitre, in small quantities, is employed to destroy any impurities arising from carbonaceous matter.

1324. The materials for the manufacture of glass are submitted to an operation called *fritting*, before they are transferred to the regular glass-furnace. It consists in exposing them to a dull red heat, by which moisture and carbonic acid are expelled, and a slight degree of chemical action induced; this also prevents the excessive swelling up of the materials in the glass-pots, and renders the process of vitrification more certain and expeditious.

The glass-pots are placed round a dome-shaped furnace, built upon arches, and open beneath for the free admission of air; there are generally six in each furnace, and they are entirely enclosed except at an orifice on the side, opening into a small recess formed by the alternate projections of the masonry and the flues, in which recess the workmen stand. Coal is the fuel employed, and the furnace is so built that a rapid current of flame may be directed round each glass-pot, which afterwards passes out with the smoke into the dome and chimney, heating a broad covered shelf in its passage, which is the annealing oven.

In the construction of the furnace and pots the greatest care is required; especially in the latter, which have not only to resist long-continued heat, but also as far as possible, the action of ingredients which tend to accelerate their fusion or vitrification. They are usually made entirely of a refractory clay, one portion being crude or unburnt, and another calcined and powdered; the latter being the remains of former furnaces when pulled down for repairs.

The frit is introduced into the glass-pots through the side-opening above-mentioned, and being heated to bright redness, becomes of a pasty consistency, and at length perfectly fuses. A quantity of impurities subside to the bottom of the pot, and partly rise to its surface. The scum, known under the name of *sandiver*, consists chiefly of saline substances, partly volatile at the high temperature of the furnace, which are removed from time to time, and sold to metal refiners as a powerful flux. The sandiver or *glass gall* being separated, the materials gradually become clearer, abundance of air-bubbles are extricated, and at length the glass appears uniform and complete; the fire round the individual pot is then damped till its contents acquire a consistency fit for working, the whole process requiring about 48 hours from the time the pots are filled. At the working heat, which is a full red, the glass has a very peculiar tenacious consistency, and as it adheres but feebly to polished metal, it is easily wrought and managed with iron tools.

1325. All glass articles require to be carefully *annealed*, that is, suffered to cool very slowly, otherwise they are remarkably brittle and apt to crack, and even fly into many pieces upon the slighest touch of any hard substance, as is well shown in the small drops of green glass suddenly cooled by dropping it into water, and called *Rupert's drops*; the instant their thin end is broken off, they crumble into a powder with a kind of explosion. This phænomenon, according to Mr. Aikin, "depends upon some permament and strong inequality of pressure, for when they are heated so red as to be soft, and merely let cool of themselves, the property of bursting is lost, and the specific gravity of the drop increased." What are termed *Bologna phials* are also made of unannealed glass, and fly to pieces when a piece of flint or other hard and angular substance is dropped into them.

1326. The exact composition of the different kinds of glass is scarcely known; the following proportions of the materials are, however, given in Messrs. Aikin's *Dictionary*, to which the reader is referred for a very valuable article upon the subject of glass, and from which I have abridged the preceding account.

Flint Glass. Specific gravity about 3.2.
120 parts of fine clear white sand
40 ——— purified pearlash
35 ——— litharge or minium
13 ——— nitre
A small quantity of black oxide of manganese.

Crown Glass or best window glass.
200 parts of soda
300 ——— fine sand
33 ——— lime
250 ——— ground fragments of glass.

Green Bottle Glass.
100 parts of sand
30 ——— coarse kelp
160 ——— lixiviated earth of wood-ashes
30 ——— fresh wood-ash
80 ——— brick clay
100 ——— fragments of glass.

Plate Glass, invented by Abraham Thevart in 1688, was first manufactured in Paris. It may be composed of
300 lbs. fine sand
200 lbs. soda
30 lbs. lime
32 oz. manganese
3 oz. cobalt azure
300 lbs. fragments of good glass.

These materials are brought into perfect fusion, and poured upon a hot copper-plate, the mass is then rolled out, annealed, and afterwards polished by grinding with sand, emery, and colcothar. The difficulty of producing a perfect plate without specks, bubbles, or waves, may easily be conceived, and this, with the risk of breakage, renders a large plate extremely expensive.

1327. The art of *colouring glass*, and of making *artificial gems*, is of an old date, and effected by metallic oxides. The *paste* for artificial gems generally contains borax, and should be kept in fusion till perfectly clear. The following proportions are recommended by M. Douault-Wieland.—*Annales de Chim. et Phys.*, Tom. xix., 57.

	Grains.
Powdered rock-crystal	4056
Red lead	6300
Pure potassa	2154
Borax	276
Arsenic.	12

M. Lançon gives the following as ingredients for a good paste :—

	Grains.
Litharge	100
White sand	75
White tartar or pot-ash	10

1328. The metals employed as colouring materials are: 1. Gold. The purple of Cassius imparts a fine ruby tint. 2. Silver. Oxide or phosphate of silver gives a yellow colour. 3. Iron. The oxides of iron produce green, yellow, and brown, depending upon the state of oxidizement and quantity. 4. Copper. The oxides of copper give a rich green; they also produce a red when mixed with a small proportion of tartar, which tends partially to reduce the oxide. 5. Antimony imparts a rich yellow. 6. Manganese. The black oxide of this metal, in large quantities, forms a black glass; in smaller quantities, various shades of purple. 7. Cobalt, in the state of oxide, gives beautiful blues of various shades; and with the yellow of antimony or lead it produces green. 8. Chrome produces fine greens and reds, depending upon its state of oxydizement.

The following are the best authorities upon the subject of coloured glasses and artificial gems :—NERI, *Art de la Verrerie.* KUNCKEL. FONTANIEU, *Encyclopédie Méthodique.* *Annales de Chim. et Phys.*, xiv., 57. AIKIN's *Dictionary*, Art. GLASS.

1329. *White Enamel* is merely glass, rendered more or less milky or opaque by the addition of oxide of tin; it forms the basis of the coloured enamels, which are tinged with the metallic oxides.

1330. The only acid body which acts energetically upon silica is the hydrofluoric acid (618.) The result of this action is a gaseous compound, which has been called *silicated fluoric acid*, or *fluo-silicic acid*; it is probably a compound of silicium and fluorine.

1331. To obtain this gaseous compound, three parts of fluor spar, and one of silica finely powdered, are mixed in a retort with an equal weight of sulphuric acid; a gentle heat is applied, and the gas evolved is to be collected over mercury.

1332. Silicated fluoric acid is a colourless gas; its odour is acrid, much resembling muriatic acid; its taste very sour; its specific gravity 3.574 compared with air; 100 cubic inches weigh 110.78 grains, so that its specific gravity to hydrogen is 49.2. It extinguishes burning bodies. It produces white fumes when in contact with damp air; and when exposed to water, two compounds of silica with fluoric acid are formed; the one *acid*, and dissolved in the water; the other containing excess of silica, and insoluble. The dry compound contains 62 *per cent.* of silica; the aqueous solution only retains 55 *per cent.* Water dissolves 260 times its bulk of this gas.

1333. When one volume of silicated fluoric acid is mixed with two of ammonia, a total condensation ensues, and a dry *silico-fluate of ammonia* results.

1334. Potassium when heated in this gas, burns and produces a brown compound, which when dissolved in water, affords *hydrofluate of potassa.*

1335. It appears from the experiments of Mr. J. F. Daniell, that silicium exists in some of the varieties of cast iron: (*Journal of Science and Arts*, Vol. ii.), and an alloy containing it has been formed by M. M. Stromeyer and Berzelius, (Gilbert's *Annalen*, xxxviii.) by exposing a mixture of pure iron, silica, and charcoal, to an intense heat.

1336. The fossils consisting of silica, pure, or nearly so, are principally the following:

i. *Rock-crystal*, or *Quartz*, which may be considered as pure silica. It crystallizes in the form of a six-sided prism, ended by six-sided pyramids; some varieties are perfectly transparent and colourless; others white and more or less opaque. Its specific gravity is 2.6. It is so hard as to give sparks when struck with steel, and is nearly infusible. The primitive crystal, which is very rare, is an obtuse rhomboid, the angles of which are 94° 24′, and 85° 36′. The finest specimens are brought from Madagascar and the Alps. The perfectly transparent crystals found near Bristol, and in Cornwall, are sometimes called *Bristol* and *Cornish diamonds*. The fine crystals are cut into ornaments, and sometimes used as a substitute for glass in spectacles; they are then termed *pebbles*, and do not so readily become scratched as glass.

Brown and yellow crystals of Quartz are found in great beauty in the mountain of Cairn Gorm in Scotland, and are much admired for seal stones, *&c.*: they are sometimes improperly termed topazes.

Purple quartz, or *amethyst*, is tinged with a little iron and manganese. *Rose quartz* derives its colour from manganese. *Prase*, or *green quartz*, contains actinolite; and *chrysoprase* is tinged of a delicate apple-green by oxide of nickel. *Avanturine* is a beautiful variety of quartz, of a rich brown colour, which, from a peculiarity of texture, appears filled with bright spangles; the finest specimens are from Spain; it is often imitated. Small crystals of quartz, tinged with iron, are found in Spain, and have been termed *hyacinths of Compostella.*

ii. *Flint*, *Chalcedony*, *Carnelian*, *Onyx*, *Sardonyx*, and *Bloodstone* or *Heliotrope*, and the numerous varieties of *Agates* are principally composed of quartz, with various tinging materials.

iii. *Opal* is among the most beautiful productions of the mineral world; it is a compound of about 90 silica and 10 water, and is distinguished by its very brilliant play of colours. The finest specimens come exclusively from Hungary. There is a variety of opal called

Hydrophane, which is white and opaque till immersed in water; it then resembles the former.

Common Opal is usually of a dirty white, and does not exhibit the colours of the noble opal; it contains silica and water, with a little oxide of iron, and is not of unfrequent occurrence. The substance called *menilite* from Menil Montant, near Paris, is nearly allied to common opal. It is found in irregular masses in a bed of clay.

iv. *Pitchstone*, so called from its resinous appearance, contains 73 *per cent.* of silica. *Obsidian*, a volcanic product, contains 78 *per cent.* of silica, and much resembles glass in appearance; and the different kinds of *pumice* are nearly of similar composition.

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SECTION XXXVIII. *Alumium.*

1337. THE earth alumina constitutes some of the hardest gems, such as the sapphire and ruby; and combined with water, it gives a peculiar softness and plasticity to some earthy compounds, such as the different kinds of clay. It is analogically considered as a metallic oxide.

1338. There can I think be little doubt of the existence of silicium and alumium, as well as of calcium, and probably magnesium, in some of the varieties of cast-iron and steel. By fusing highly carburetted steel with alumina, a peculiar alloy results, which is white, granular, and brittle, and which yields on analysis 6.4 *per cent.* alumina. On fusing 67 parts of this alloy with 500 of steel, a compound is obtained, which possesses all the characters of the best Bombay wootz (761), and like it, when its surface is polished and washed over with dilute sulphuric acid, exhibits the striated appearance called *damask*, for which the celebrated sabres of Damascus are remarkable, and which renders it probable that they also are made of wootz. (*Quarterly Journal of Science and Arts*, ix.). Many of the varieties of cast-iron afford lime and silica when dissolved in acids, and it is highly probable that those substances, as well as the alumina in the wootz, exist combined with the iron in their deoxidized or metallic state.

1339. To obtain *pure alumina* we add carbonate of ammonia to a solution of alum, wash, and ignite the precipitate; it is a tasteless white substance, forming a cohesive mass with water, and retaining water even at a red heat. Its specific gravity is 2. It is soluble in soda and potassa, and forms compounds with baryta, strontia, lime, and silica. It is an essential ingredient in pottery and porcelain.

1340. One of its saline combinations is of important use in the arts, namely, *alum*; a *triple sulphate of alumina and potassa.* This salt is usually prepared by roasting and lixiviating certain clays containing pyrites; to the leys, a certain quantity of potassa is added, and the triple salt is obtained by crystallization*.

Alum has a sweetish astringent taste. It dissolves in 5 parts of water at 60°, and the solution reddens blues. It furnishes octoëdral crystals.

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* Sulphate of alumina will not crystallize; but if a solution of sulphate of potassa be added to solution of sulphate of alumina, small octoëdral crystals of alum are precipitated.

When heated, it loses water of crystallization and a part of its acid, and becomes a white spongy mass. In its crystalline form it consists, according to some recent experiments made by Mr. R. Phillips, of

Sulphate of alumina	123.00
Bi-sulphate of potassa	119.32
Water	187.00
	429.32

Mr. Phillips adopts the number 24 as the representative of alumina, and considers alum as a compound of 2 proportionals of sulphate of alumina, 1 of bi-sulphate of potassa, and 22 of water. These proportions, therefore, would be

Bi-sulphate of potassa		= 128
Sulphate of alumina . .	61.5 × 2	= 123
Water	9. × 22	= 198
		449

1341. When alum is exposed to an intense heat, it loses water, and a portion of acid; but the whole of the acid cannot be expelled. It becomes light and spongy; and in this state is called in the *Pharmacopœia*, *Alumen ustum*, or *exsiccatum*. If alum contain excess of potassa it forms cubic crystals, and is known under the name of cubic alum. Some varieties of alum contain ammonia.

1342. When alum is ignited with charcoal, a spontaneously inflammable compound results, which has long been known under the name of *Homberg's pyrophorus*. The potassa appears to be decomposed in this process, along with the acid of the alum, and pyrophorus is probably a compound of sulphur, charcoal, and potassium, with alumina.

Pyrophorus is most successfully prepared by the following process. Mix equal parts of honey, or of brown sugar and powdered alum, in an iron ladle, melt the mixture over a fire, and keep it stirred till dry: reduce the dry mass to powder, and introduce it into a common phial coated with clay, and placed in a crucible of sand. Give the whole a red heat, and when a blue flame appears at the neck of the phial, allow it to burn about five minutes, then remove it from the fire; stop the phial, and allow it to cool, taking care that air cannot enter it.

1343. Alum is of extensive use in the arts, more especially in dyeing and calico-printing, in consequence of the attraction which alumina has for colouring matter.

1344. A *triple sulphate of alumina and soda* is described in the *Quarterly Journal of Science and Arts*, (viii. 386.) in the form of irregular efflorescent octoedra: it appears to contain

2	proportionals sulphate of alumina	61.5 × 2	= 123
1	———— bi-sulphate of soda		= 112
28	———— water	9. × 28	= 252
			487

1345. The remaining salts of alumina with the exception of the acetate, which remains to be described, are of little importance; what is known respecting them is fully detailed by Dr. Thomson.—*System*, Vol. ii., p. 510.

1346. Under the term *corundum* certain mineral substances have been included, composed of alumina, nearly pure.

i. *Perfect corundum* occurs crystallized in six-sided prisms, transparent and colourless. Its specific gravity is about 4. When blue, it constitutes the *sapphire;* when red, the *ruby;* when yellow, the *oriental topaz*, or *chrysolite*. These gems are principally found in alluvial deposits. They are mostly procured from Ceylon and Pegu; they have also been found in France and in Bohemia.

ii. *Imperfect corundum*, or *adamantine spar* and *emery*, are nearly analogous in composition to the former; they contain from 3 to 5 *per cent.* of silica and 1 to 2 of oxide of iron.

iii. *Spinelle* or *balass ruby*, is found in octoëdral crystals, of a red colour. It is composed of 74.5 alumina, 15.5 silica, 3.25 magnesia, 1.5 oxide of iron, and traces of lime and oxide of chrome. The *ceylanite* or *pleonaste*, is a variety of Spinelle. A variety, containing oxide of zinc, is called *zinc spinelle*, or *automalite*.

iv. The mineral, called *Wavellite*, or *hydrargillite*, is a compound of alumina, phosphoric acid, and water. It is found in Devonshire, in small radiated nodules upon clay-slate. According to Berzelius, (*Annales de Chim. et Phys.*, Tom. xii.) 100 parts afford

Alumina	35.35
Phosphoric acid	33.40
Fluoric acid	2.06
Lime	0.50
Oxides of iron and manganese	1.25
Water	26.80
	99.36

v. The *occidental topaz*, found chiefly in Saxony, Siberia, Brazil, and Scotland, consists of alumina, silica, and fluoric acid. The *schorlous beryl* or *pycnite*, and the *pyrophysalite*, are nearly of the same composition.

vi. *Cryolite*, a rare substance hitherto only found in Greenland, consists of alumina, soda, and fluoric acid. It is white, amorphous, and translucent.

vii. A mineral, called *native alumina*, is found upon the Sussex coast, near New-haven. It is white and friable, and occurs massive and incrusting. It contains alumina and sulphate of lime.

1347. A very numerous and important class of minerals consists of a combination of silica with alumina, in various proportions, and with the occasional addition of the fixed alcalis or alcaline earths, and a few of the other metallic oxides: the principal of these, which are not elsewhere mentioned, are the following:

i. *Zeolite.*—Of this mineral there are several varieties. The principal are the *radiated* or *mesotype;* the *nacreous* or *stilbite;* the *efflorescent* or *laumonite;* and the *cubic* or *analcime*. These minerals fuse and intumesce before the blow-pipe, and mostly form gelatinous solutions in the acids. The following is Vauquelin's analysis of a radiated or acicular zeolite:

Silica	50.24
Alumina	29.30
Lime	9.46
Water	10.00

ii. *Apophyllite* and *Chabasite* are nearly of the same composition; except that the latter contains about 9 *per cent.* of potassa and soda.

iii. *Garnet* occurs massive, but generally crystallized in dodecaëdra. The *precious garnet* is red and transparent; the *common garnet*, red, brown, or green. According to Vauquelin, the precious garnet consists of

Silica	36
Alumina	20
Oxide of iron	41
Lime	3

The *cinnamon stone* of Ceylon is nearly of similar composition.

iv. *Melanite*, or *black garnet*, contains, upon the same authority,

Silica	35
Alumina	6
Lime	32
Oxides of iron and manganese	25

v. *Leucite*, or *white volcanic garnet*, contains, according to Klaproth,

Silica	54
Alumina	24
Potassa	21

vi. *Vesuvian*, or *idocrase*, is brown or yellow red, and is found crystallized in the masses of rock ejected by Vesuvius and Etna. It has also been found in the Alps and in Siberia. The Neapolitan lapidaries call it *chrysolite of Vesuvius*. In composition it differs little from melanite.

vii. *Staurotide*, or *grenatite*, crystallizes in four and six-sided prisms often crossing each other. It consists of

Silica	33
Alumina	44
Lime	3.8
Oxides of iron and manganese	14

viii. *Sodalite* and *natrolite* are minerals containing a considerable portion of soda. The former has been analyzed by Dr. Thomson. It has hitherto only been found in Greenland and on Vesuvius. Its colour is light green, and it occurs massive and crystallized in rhomboidal dodecaëdra. It consists of

38.42	silica
27.48	alumina
23.50	soda
2.70	lime
3.00	muriatic acid
1.00	oxide of iron
2.10	volatile matter.

IX. *Prehnite* is of a greenish colour, and radiated fracture. It occurs massive and crystallized in prisms. A lamellar variety has been called *koupholite*. It is found near the Cape of Good Hope, and in France and Scotland.

X. *Spodumene*, or *triphane*, is a mineral already alluded to in the section on Lithium. It is nearly allied to feldspar, and consists of

65	silica
25	alumina
8	lithia
2	oxide of iron.
100	

XI. *Scapolite*, and *Elaolite*, or *Fettstein*, are minerals hitherto found only in Norway: they contain about 45 *per cent.* of silica, and 33 of alumina. The scapolite contains about 18 *per cent.* of lime; the *elaolite*, the same proportion of potassa and soda.

XII. *Nephritic stone*, or *jade*, which is found in the Alps, and in China and India, contains, according to Saussure,

53.7	silica
12.7	lime
7	oxide of iron and manganese
10.7	soda
8.5	potassa
7.4	water and loss.
100.0	

The Chinese cut this substance into figures, and it is sometimes used for the handles of cutting-instruments. In New Zealand and other islands of the Pacific Ocean it is used for cutting instruments, in consequence of its hardness and toughness. Hence it has been called *axe stone*.

XIII. *Schorl* and *Tourmalin* consist principally of silica, alumina, and oxide of iron. They occur in prismatic crystals of a black colour.

XIV. *Thallite*, *epidote*, or *pistacite*, is nearly allied in composition to schorl. It occurs in green prismatic crystals.

XV. *Axinite*, or *thumerstone*, is found crystallized in flat oblique rhombs, of a brown, bluish, or grey tint, and transparent. It consists, according to Vauquelin, of

Silica	44
Alumina	18
Lime	19
Oxide of iron	14
Oxide of manganese	4

xvi. *Cyanite* is of a blue and grey colour, translucent, and occurs massive and prismatic. It consists, according to Klaproth, of

Alumina	55.5
Silica	43.0
Oxide of iron	0.5

xvii. *Lepidolite* occurs massive, and of a purplish colour and lamellar texture. According to Klaproth, it contains

Silica	54.5
Alumina	38.25
Potassa	4.
Oxide of iron and manganese	0.75

xviii. *Actinolite* is of a green colour, and generally occurs in aggregated masses of prismatic crystals. It contains

Silica	50.
Lime	9.7
Magnesia	19.2
Alumina	0.7
Oxides of chrome and iron	8.

xix. *Tremolite* is nearly white, fibrous and semi-transparent. It contains

Silica	62
Lime	14
Magnesia	13
Oxide of iron	6

xx. *Asbestos* is a soft fibrous flexible mineral, of a white or greenish tint, composed of

Silica	60
Magnesia	30
Lime	6
Alumina	4

Amianthus, *mountain cork*, and *mountain wood*, are varieties of asbestos.

xxi. *Lapis lazuli* consists of

Silica	46
Carbonate of lime	28
Alumina	14
Sulphate of lime	6.5
Oxide of iron and water	5

The blue colour is probably derived from some principle which has hitherto escaped analysis. It is prepared for painters under the name of *ultra-marine*.

xxii. *Harmotome*, *Staurolite*, or *Cross-stone*, occurs in small quadrangular prisms terminated by four rhombic planes, crossing each other. It is also found in single crystals. It is found at Andreasberg, in the

Hartz, and at Strontian, in Scotland. It consists, according to Klaproth, of

Silica	49
Alumina	16
Baryta	18
Water	15

xxiii. *Augite* is a mineral of a black or brownish green colour, found in volcanic products, and in some basalts. *Sahlite* and *coccolite* are varities of augite. It is composed of

Silica	52
Lime	13
Oxide of iron and manganese	16
Magnesia	10
Alumina	9

xxiv. *Datholite* is a combination of

Silica	38
Lime	34
Boracic acid	22
Water	4

It has only been found in Norway.

1348. Under the term *Clay* is comprehended a variety of mixtures of silica and alumina, more or less pure, and characterized by a peculiar plasticity in their moist state. The following are the principal varieties.

1. *Porcelain Clay*, derived principally from the decomposition of feldspar, and containing silica and alumina, sometimes with traces of oxide of iron; it is very difficult of fusion. 2. *Marly Clay*, which, with silica and alumina, contains a portion of carbonate of lime; it is much used in making pale bricks, and as a manure, and when highly heated enters into fusion. 3. *Pipe Clay*, which is very plastic and tenacious, and requires a higher temperature than the preceding for fusion; when burned it is of a cream colour, and used for tobacco-pipes and white pottery 4. *Potters' Clay*, is of a reddish or grey colour, and becomes red when heated; it fuses at a bright red heat: mixed with sand it is manufactured into red bricks and tiles, and is also used for coarse pottery.

1349. The better kind of *pottery*, called in this country *Staffordshire ware*, is made of an artificial mixture of alumina and silica; the former obtained in the form of a fine clay, from Devonshire chiefly; and the latter consisting of chert or flint, which is heated red-hot, quenched in water, and then reduced to powder. Each material, carefully powdered and sifted, is diffused through water, mixed by measure, and brought to a due consistency by evaporation: it is then highly plastic, and formed upon the potter's wheel and lathe into various circular vessels, or moulded into other forms, which, after having been dried in a warm room, are enclosed in baked clay cases resembling bandboxes, and called *seggars*: these are ranged in the kiln so as nearly to fill it, leaving only space enough for the fuel; here the ware is kept red-hot for a considerable time, and thus brought to the state of *biscuit*. This is afterwards *glazed*, which is done "by dipping the biscuit ware into a tub containing a mixture of about 60 parts of litharge, 10 of clay, and 20 of ground flint, diffused in water to a creamy consistence, and when taken out enough adheres to the piece to give an uniform glazing when again heated. The pieces are then again packed up in the seggars, with small bits of pottery interposed between each, and fixed in a kiln as before. The glazing mixture fuses at a very moderate heat, and gives an uniform glossy coating, which finishes the process when it is intended for common white ware."—*Aikin's Dictionary*. Art. POTTERY.

1350. The patterns upon ordinary porcelain, which are chiefly in blue, in consequence of the facility of applying cobalt, are generally printed off upon paper, which is applied to the plate or other article while in the state of biscuit, and adheres permanently to the surface when heat is properly applied.

1351. The manufacture of *porcelain* is a most refined branch of art; the materials are selected with the greatest caution, it being necessary that the compound should remain perfectly white after exposure to heat: it is also required that it should endure a very high temperature without fusing, and at the same time acquire a semivitreous texture and a peculiar degree of translucency and toughness. These qualities are united in some of the oriental porcelain, or *China*, and in some of the old Dresden, but they are rarely found co-existent in that of modern European manufacture. Some of the French and English porcelain, especially that made at Sèvres and at Worcester, is extremely white and duly translucent, but it is more apt to crack by sudden changes of temperature; more brittle, and consequently requires to be formed into thicker and heavier vessels; and more fusible than the finest porcelains of Japan and China.

1352. The colours employed in painting porcelain are the same metallic oxides enumerated for colouring glass, and in all the more delicate patterns they are laid on with a camel-hair pencil, and generally previously mixed with a little oil of turpentine. Where several colours are used, they often require various temperatures for their perfection, in which case those that bear the highest heat are first applied, and subsequently those which are brought out at lower temperatures. This art of painting on porcelain or in enamel is of the most delicate description; much experience and skill are required in it, and with every care there are frequent failures; hence it is attended with considerable expense. The gilding of porcelain is generally performed by applying finely-divided gold mixed up with gum-water and borax; upon the application of heat the gum burns off, and the borax vitrifying upon the surface causes the gold firmly to adhere; it is afterwards burnished.

1353. In the manufacture of various kinds of pottery employed in the chemical laboratory, and especially in regard to *crucibles*, many difficulties occur; and many requisites are necessary which cannot be united in the same vessel: to the late Mr. Wedgwood we are indebted for vast improvements in this as well as in other branches of the art.

Crucibles composed of one part of pure clay mixed with about three parts of coarse and pure sand, slowly dried and annealed, resist a very high temperature without fusion, and generally retain metallic substances; but where the metals are suffered to oxidize, there are few which do not act upon any earthen vessel, and some cause its rapid fusion, as the oxides of lead, bismuth, *&c.* Where saline fluxes are used, the best crucibles will always suffer, but platinum may often be employed in these cases, and the chemist is thus enabled to combat many difficulties which were nearly insurmountable before this metal was thus applied.

Whenever siliceous and aluminous earths are blended, as in the mixture of clay and sand, the compound softens, and the vessel loses its shape when exposed to a long-continued white heat, and this is the case with the *Hessian* crucibles: consequently, the most refractory of all vessels are those made entirely of clay, coarsely-powdered burned clay being used as a substitute for the sand. Such a compound resists the action of saline fluxes longer than any other, and is therefore used for the pots in glass furnaces. A Hessian crucible lined with purer clay is rendered much more retentive; and a thin china cup or other dense porcelain resists the action of saline matters in fusion for a considerable time.

Plumbago is a very good material for crucibles, and applicable to many purposes: when mixed with clay it forms an infusible compound and is protected from the action of the air at high temperatures; it is well calculated for small table furnaces. Wrought-iron crucibles are used for the fusion of several metallic substances which melt at a bright red heat.

1354. Under the term *Lutes* a variety of compounds are used by the practical chemist for the purpose of securing the junctures of vessels or protecting them from the action of heat. Slips of wetted bladder, linseed meal made into a paste with gum-water, white of egg and quicklime, glaziers' putty which consists of chalk and linseed oil; and *fat lute* composed of pipe clay and drying oil well beaten to a stiff mass, are very useful lutes for retaining fumes and vapours and joining vessels to each other, but earthy compounds are required to withstand the action of a high temperature.

Windsor loam, or an artificial mixture of clay and sand well beaten into a stiff paste, and then thinned with water and applied by a brush in successive layers, to retorts, tubes, gun-barrels, *&c.*, enables them to bear a very high temperature; if a thick coating is required, great care should be taken that the cracks are filled up as it dries, and often a little tow mixed up with the lute renders it more permanent and applicable. If the lute is intended to vitrify, as, for instance, to prevent the porosity of earthenware at high temperatures, a portion of borax or of red lead may be mixed up with it.

1355. ***Mortar***, or the cement used in building, is a compound of several earthy substances, one of which is always lime: for much valuable information relating to this important subject we are indebted to the late Mr. Smeaton (*History of the Eddystone Lighthouse*), and an excellent summary of the principal facts connected with it will be found in AIKIN'S *Dictionary*, (Art. CEMENTS.) The ordinary mode of making mortar consists in mixing a quantity of common sand with slacked lime, without any careful attention to the quantity or purity of the materials; but it has been shown by Mr. Smeaton, that the presence of unburnt clay prevents the induration of the mortar, and the sand used in London always contains it; the lime too is often imperfectly burned and seldom duly selected; that which contains a portion of alumina and oxide of iron being preferable to the purer varieties; hence the advantage of *Dorking* lime, or *meager lime*, as it is usually called. The sand should be sharp and large grained, and perfectly free from salt, which always prevents the mixture from becoming hard. The addition of calcined ferruginous clay, or calcined basalt, or black oxide of iron, gives mortar the property of becoming hard under water.

The mutual action which the substances constituting the different kinds of mortar undergo, has hitherto been but imperfectly examined by the chemist; to M. Vicat we are indebted for a curious and important series of investigations upon this subject, and his work may be consulted with much advantage, by those who are concerned in investigations of this nature.—*Recherches Expérimentales sur les Chaux de Construction, les Bétons, et les Mortiers ordinaires.* Paris, 1818.

SECTION XXXIX. *Zirconium.*

1356. THE earth *zircon*, or the *oxide of zirconium*, is a white insipid substance; specific gravity 4.3; it is found in the zircon or *jargon* of Ceylon. It is characterized by insolubility in pure alcalis, but is soluble in alcaline carbonates. Its combinations with the acids are of difficult solubility or insoluble, and have been very little inquired into.

i. The *zircon*, or *jargon*, is a mineral, usually of a grey yellowish, or reddish-brown colour, crystallized in octoëdrons and four-sided prisms, and generally semi-transparent.

ii. *Zirconia* is contained in the *hyacinth*, which is also found in Ceylon, and in various parts of Europe. Its usual colour is red or reddish, and its crystals small flattened octoëdra, or four-sided prisms. These minerals contain about 70 *per cent.* of zirconia each, the remainder being silica, with a trace of oxide of iron.—KLAPROTH's *Beitrage*, Vol. i., pp. 222 and 231.

1357. Zirconia is obtained by the following process:

Mode of obtaining.

Reduce the stone to a fine powder, having previously heated it to redness, and quenched it in water. Mix the powder with nine times its weight of pure potassa, and gradually project it into a red-hot silver crucible, and keep it in perfect fusion for two hours. When the crucible has cooled, reduce the mass to a fine powder, and boil it in distilled water. Boil the undissolved residue in muriatic acid; filter, and evaporate to dryness; re-dissolve the dry mass in distilled water, and precipitate by carbonate of soda. The carbonate of zirconia which falls may be decomposed by heat.

The following method of obtaining pure zirconia is recommended by M. M. Dubois and Silveira.—*Annales de Chim. et Phys.*, xiv. 110:

Powder the zircons very fine, mix them with two parts of pure potassa, and heat them red-hot in a silver crucible for an hour. Treat the substance obtained with distilled water, pour it on a filter, and wash the insoluble part well; it will be a compound of zirconia, silica, potassa, and oxide of iron. Dissolve it in muriatic acid, and evaporate to dryness, to separate the silica. Re-dissolve the muriates of zirconia and iron in water; and to separate the zirconia which adheres to the silica, wash it with weak muriatic acid, and add it to the solution. Filter the fluid and precipitate the zirconia and iron by pure ammonia;

wash the precipitates well, and then treat the hydrates with oxalic acid, boiling them well together, that the acid may act on the iron, retaining it in solution whilst an insoluble oxalate of zirconia is formed. It is then to be filtered, and the oxalate washed, until no iron can be detected in the water that passes. The earthy oxalate is, when dry, of an opaline colour; after being well washed, it is to be decomposed by heat in a platinum crucible. Thus obtained, the zirconia is perfectly pure, but is not affected by acids. It must be re-acted on by potassa as before, and then washed until the alcali is removed. Afterwards dissolve it in muriatic acid, and precipitate by ammonia. The hydrate thrown down, when well washed, is perfectly pure, and easily soluble in acids.

1358. The composition of zirconia has been estimated by Sir H. Davy (*Elements of Chemical Phil.* p. 361.) at

37.	zirconium
8	oxygen.
45	

◆

Section XL. *Glucinum.*

1359. The earth *glucina* was discovered by Vauquelin in the beryl; it also exists in the emerald of Peru. It is white and insipid; its specific gravity = 2.97. It dissolves in caustic potassa and soda, and thus resembles alumina, but differs from yttria. Again it differs from alumina, but resembles yttria, in being soluble in carbonate of ammonia; it is much more soluble in this solution than yttria. With the acids it forms saline compounds of a sweetish astringent taste.

i. The *beryl* is found in primitive rocks in many parts of the world, but especially fine in Siberia. It is usually transparent, and pale green or blue. It crystallizes in six-sided prisms.

ii. The *emerald* is principally found in Peru, crystallized in regular six-sided prisms, the edges or angles of which are sometimes replaced by facets. Its colour is green, and it is either transparent or translucent. The following are their components parts.—Vauquelin, *Journal des Mines*, No. xxxvi, and No. xliii:

	Beryl.	Emerald.
Silica	68	64.5
Alumina	15	16
Glucina	14	13
Oxide of Chrome	—	3
Oxide of iron	1	—
Lime	2	1.5
Water	—	2
	100	100

iii. Glucina is also found in the *euclase*, a very scarce Peruvian mineral, composed, according to Berzelius, of

Silica	44.33
Alumina	31.83
Glucina	23.84
	100.00

1360. To obtain glucina from either of these minerals, proceed as follows :—Reduce it to a fine powder, and fuse it with thrice its weight of potassa ; dissolve in a dilute muriatic acid ; evaporate to dryness ; re-dissolve in water, and precipitate by carbonate of potassa. Dissolve this precipitate in sulphuric acid and add a little sulphate of potassa, and on evaporation crystals of alum will be obtained. These being separated, add excess of carbonate of ammonia to the residuary liquor, which will retain glucina in solution, but the alumina will be precipitated ; filter, and evaporate to dryness, and apply a red heat ; glucina remains.

1361. From the experiments of Davy, this earth may be regarded as consisting of

21.3 glucinum
8. oxygen

29.3 glucina.

◆

Section XLI. *Yttrium.*

1362. In 1794 Professor Gadolin discovered a new earth in a mineral from the quarry of Ytterby in Sweden, to which Ekeberg, in 1797, gave the name of *Yttria.* The mineral has since been termed *Gadolinite.* Oxide of yttrium, or yttria, may be obtained by the following process : Pulverise the mineral and boil in repeated portions of nitromuriatic acid ; evaporate nearly to dryness, dilute with water, and filter ; evaporate to dryness, ignite the residue for some hours in a close vessel, re-dissolve and filter. To this solution add ammonia, which throws down yttria and oxide of cerium ; heat the precipitate red-hot, dissolve it in nitric acid, and evaporate to dryness ; dilute with 150 parts of water, and put crystals of sulphate of potassa into the liquid. The crystals gradually dissolve, and, after some hours, a white precipitate appears of oxide of cerium, the whole of which must be separated by a repetition of this process. The liquor is then to be filtered, and the addition of pure ammonia forms a precipitate of yttria, which is to be washed and heated red-hot.—Berzelius in Thomson's *Chemistry.* Vol. i. p. 357.

1363. Yttria is insipid, white, and without action on vegetable colours. It is insoluble in water, but very retentive of it. Insoluble in pure alcalis, but readily soluble in carbonated alcalis. It forms salts which have a sweetish austere taste, and which have been little examined. From indirect experiments it probably contains 25 *per cent.* oxygen ; hence it may be regarded as consisting of

32 yttrium
8 oxygen

40 yttria.

◆

Section XLII. *Thorinum.*

1364. In examining some varieties of gadolinite and certain ores of cerium, Berzelius obtained a new metallic oxide, the base of which he has called *thorinum.* The accounts hitherto published of the mode of procuring this substance, are by no means sufficiently clear or circumstantial to enable the student to repeat them, but the process of analysis of the minerals containing it will be found in the section on the compounds of thorinum in the ensuing chapter.

1365. Thorina differs from alumina in being insoluble in solution of potassa; from yttria, by its astringent taste without sweetness, and by its neutral solutions affording a precipitate when boiled. From zirconia it differs in the following properties: 1. After being heated to redness it is still soluble in acids. 2. Sulphate of potassa occasions no precipitate in its solutions. 3. It is precipitated by oxalate of ammonia. 4. Sulphate of thorina crystallizes, while sulphate of zirconia does not. —Thomson, Vol. i. p. 567.

CHAPTER VI.

OF THE ASSAY AND ANALYSIS OF METALLIFEROUS COMPOUNDS.

1366. The chemical history of the metals, given in the preceding chapter of this volume, includes some account of the method of analyzing certain of their compounds, but upon this subject many details have necessarily been omitted in the different sections treating of the metals individually, in consequence of the numerous digressions that such discussion would have introduced; in the present chapter, therefore, it is proposed to describe such analytical processes as have not previously been adverted to, and are of frequent occurrence in the chemical laboratory; and likewise to point out the means of detecting impurities and adulterations in the various chemical products used in medicine and in the arts.

Distilled water.

1367. It is scarcely necessary to observe that in all analytical operations distilled water is to be employed, and that the purity of the tests and re-agents must be previously ascertained: it is also convenient that they should be of some known degree of strength or concentration.

Balance.

1368. Among the most important apparatus of the chemical analyst, is a good balance; he will generally find it convenient to employ two; one, extremely delicate and capable of weighing from one-hundredth of a grain up to fifty grains; the other, less sensible, but turning with one-tenth of a grain, when loaded with about an ounce in each scale. Larger balances are often requisite for weighing from one ounce to five or six pounds.

Mortars.

1369. For the disintegration of very hard substances, mortars of hard steel, agate, or phorphyry, are generally used, and the substance should be accurately weighed before and after pulverization, in order to ascertain whether it has suffered any increase from the abrasion of the mortar. The aggregation of many very hard stony substances may be diminished by heating them red-hot and quenching in water; but care should be taken to ascertain the nature and quantity of any loss which they may sustain in this operation.

Quantity.

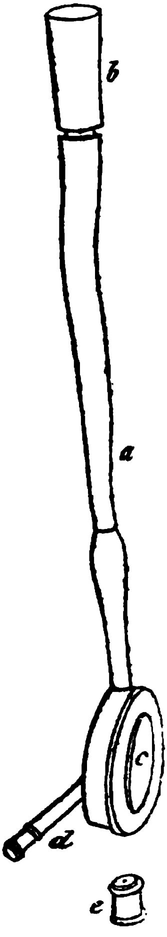
1370. The proportion of any substance for an analysis varies, in ordinary cases, from twenty to one hundred grains; fifty grains is, generally speaking, a convenient quantity, and where there is no scarcity of the material, it is often advantageous to operate upon two or three portions at once, using each portion for ascertaining a distinct component part.

Crucibles.

1371. The crucibles employed in these analytical operations are either metallic, earthenware, or porcelain. Of the former, platinum, silver, and iron are chiefly useful; platinum resists the action of the greater number of acids, but it is acted upon by alcaline substances; pure silver is chiefly useful for alcaline fusions, but as it melts at a red heat, some care is requisite in its employment; for metallic substances, Hessian and Wedgwood crucibles are required; the former, when well made, resist a very high heat without fusion, and bear sudden changes of temperature; the latter are apt to crack, and should therefore be carefully heated, or placed in a Hessian crucible. It is often necessary to line a crucible with charcoal, which is most conveniently effected by mixing finely-powdered charcoal with a very little linseed-meal, and beating it into a stiff paste with a small addition of water; the crucible is then dipped into water, and its interior lined to the requisite thickness; on applying heat, the linseed-meal burns, but the coating is not injured.

Blowpipe.

1372. In the examination of mineral substances, the blow-pipe is a most useful and necessary auxiliary to our other operations; it affords a simple and convenient means of heating to a very high degree, and almost instantaneously, any substance sufficiently small to be enveloped in its flame; and the experienced eye is thus frequently enabled to anticipate, with much precision, the nature of the substance submitted to experiment.



There are numerous forms of the blow-pipe, among which, that represented in the annexed cut is perhaps the most convenient. It consists of a brass tube *a*, with an ivory mouth-piece *b*; the other end of the tube terminates in a circular box, from which issues the small tube *d*, moveable in any direction round the centre *c*, by which any degree of obliquity may conveniently be given to the flame; *e* is a brass jet which fits upon the tube *d*.

1373. The following observations respecting the use of the blow-pipe, and its action upon several substances, are extracted from Mr. Children's *Essay on Chemical Analysis*: a work from which the student may derive much valuable information.

Management of the blow-pipe.

A continued stream of air is absolutely essential, to produce which, without fatigue to the lungs, an equable and uninterrupted inspiration must be maintained by inhaling air through the nostrils, whilst that in the mouth is forced through the tube by the compression of the cheeks. A little practice will make this operation easy, but at first considerable lassitude is generally experienced in the buccinator muscles. After habit has rendered the operation familiar, a current may be kept up for ten or fifteen minutes, without inconvenience. A large wax candle supplies the best flame, which being urged by the blast, exhibits two distinct figures; the internal flame is conical, blue, and well defined, at the apex of which the most violent degree of heat is excited; the external is red, vague, and undetermined, and of very inferior temperature to the former.

The substance to be submitted to the action of the blow-pipe, which should not be larger than a small pepper-corn, must be supported either on charcoal, or a slip of platina or silver foil, or be held in a pair of platina pincers. In the first case it may be placed in a cavity in the charcoal, and another piece laid over it to prevent its being carried off by the blast. The metallic supports are used when the subject of the experiment is intended to be exposed to the action of heat only, and might be altered by contact with the charcoal. If a very intense heat be required the foil may be laid on charcoal. Salts and volatile substances, are to be heated in glass tubes, closed at one end, and enlarged according to circumstances, so as to form small matrasses.

The exterior flame should first be directed on the substance, and when its action is known, then the interior blue flame. Notice should be taken, whether the matter decrepitates, splits, swells up, liquefies, boils, vegetates, changes colour, smokes, is inflamed, becomes obedient to the magnet, *&c.** ; when the action of heat alone has been ascertained, it will be necessary to examine what further change takes place, by fusing it with various fluxes, and also whether it be capable of reduction to the metallic state.

Fluxes. The three most useful fluxes, are the triple phosphate of soda and ammonia, subcarbonate of soda and borax. These are to be kept ready pulverised, and when used, a sufficient quantity may be taken up by the moistened point of a knife; the moisture causes the particles to cohere and prevents their being blown away, when placed on the charcoal. The flux must be melted into a clear bead, and the substance then placed on it, and submitted, first to the action of the exterior, and then to that of the interior, flame. The appearances which ensue must be observed; as,

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*M. Hany has proposed the following ingenious method of rendering very weak magnetic attractions perceptible:

If we conceive the needle to be removed a little from the plane of its magnetic meridian, its directing force will immediately tend to restore it, and with a power proportionate to the size of the angle which the needle makes with the magnetic meridian. Before any substance can act on the needle, it will have to overcome the directing force, as well as the friction at the point of suspension; obstacles which may prevent the effect of very slight attractions from being perceived. To diminish the force opposed to the action of the needle, M. Hauy places a magnetic bar at a certain distance from it, on the same level and in the direction of its axis, but with its poles situated contrary to those of the needle. If we suppose the magnetic bar to be placed to the south of the needle, the south pole of the magnet and the needle will be opposed to each other, and if the magnet be made to approach the needle, the latter will move on its centre towards one side or the other, till an equilibrium is produced between the mutual action of the magnet and needle, and that of the needle and the earth. Coulomb has shown that in proportion as the needle deviates from its natural position, the increments of power necessary to produce equal effects, are in a decreasing ratio; so that when it has moved through nearly a quarter of a circle, a very small attractive power will be sufficient to influence it. When it is in this position, that is, nearly at right angles with the magnetic meridian, the needle is in its most sensible state; and is affected if any substance containing the most minute portion of iron be presented to it.

Hauy has by this method detected iron in several minerals where its presence was not suspected, or where it was supposed to exist in a state not liable to be affected by the magnet. —*Annals of Philosophy*, Vol. xii. p. 117.

1st. If the substance be dissolved, and whether with or without effervescence:

2nd. The transparency, and colour of the glass whilst cooling;

3rd. The same circumstances, when cold;

4th. The nature of the glass formed by the exterior flame;

5th. Also, by the interior flame.

6th. The particular appearances with each of the fluxes.

Subcarbonate of soda does not form a bead on charcoal, but with a certain degree of heat is absorbed; it must therefore be added in very small quantities, and a gentle heat used at first, which will promote combination without the absorption of the alkali. Some minerals combine readily with very small portions of soda, but difficultly if more be added, and are absolutely infusible with it in great excess; and when the substance has no affinity for this flux, it is absorbed by the charcoal, and no combination ensues.

When the mineral contains sulphur or sulphuric acid, the glass acquires a deep yellow colour, which by the light of a lamp appears red, as if produced by copper.

If the glass bead become opaque as it cools, so as to render the colour indistinct, it should be broken and a part of it mixed with more of the flux, till the colour becomes purer, and distinct. To make the colour more perceptible, the bead may be flattened whilst soft, or drawn out to a thread.

If it be wished to *oxidate* a metallic substance, combined with either of the fluxes, the glass is first heated intensely, and when *fused*, gradually withdrawn from the point of the blue flame, and the operation repeated, as often as necessary, using a jet of large aperture. The addition of a little nitre also assists the oxidation. For the *reduction* of metallic oxides, the glass bead is to be kept in fusion on charcoal, as long as it remains on the surface and is not absorbed, that the metallic particles may collect into a globule. It is then to be fused with an additional quantity of soda, which will be absorbed by the charcoal, and the spot where the absorption has taken place, strongly ignited by a tube with a small aperture. By continuing the ignition, the portion of metal which was not previously reduced, will now be brought to the metallic state, and the process may be assisted, by placing the bead in a smoky flame, so as to cover it with a soot that is not easily blown off.

The beads which contain metals frequently have a metallic splendour, which is most easily produced by a gentle, fluttering, smoky flame, when the more intense heat has ceased. With a moderate heat the metallic surface remains; and by a little practice it may generally be known whether the substance under examination contains a metal or not. But the glass of borax alone sometimes assumes externally a metallic appearance.

When the charcoal is cold, that part impregnated with the fused mass should be taken out with a knife, and ground with distilled water in an agate mortar. The soda will be dissolved; the charcoal will float, and may be poured off; and the metallic particles will remain in the water, and may be examined.

In this manner most of the metals may be reduced.

Action of the Blowpipe on the Earths and Metallic Oxides.

Baryta (627), when containing water, melts and spreads on the charcoal. Combined with sulphuric acid, it is converted, in the *interior* flame, into a sulphuret, and is absorbed by the charcoal, with effervescence, which continues as long as it is exposed to the action of the instrument.

Strontia (652), if combined with carbonic acid, when held in small thin plates with platinum forceps in the *interior* flame, has its carbonic acid driven off, and on the side of the plate furthest from the lamp, a red flame is seen, sometimes edged with green, and scarcely perceptible but by the flame of a lamp. Sulphate of strontia is reduced in the *interior* flame to a sulphuret; dissolve this in a drop of hydrochloric acid, add a drop of alcohol, and dip a thin slip of deal in the solution; it will burn with a fine red flame.

Lime (618).—The carbonate is easily rendered caustic by heat; it then evolves heat on being moistened, turns paper stained with turmeric brown, and is infusible before the blow-pipe. The sulphate is easily reduced to a sulphuret, and possesses, besides the property of combining with fluor spar at a moderate heat, forming a clear glass. The fluor should be rather in excess.

Magnesia (671) produces, like strontia, an intense brightness in the flame of the blow-pipe. A drop of a solution of cobalt being added to it, and then dried and strongly ignited, a faint flesh red colour, scarcely visible by the light of a lamp, is produced.

Magnesia may in this manner be detected in compound bodies, if they *do not* contain much metallic matter, or a quantity of alumina, exceeding that of the magnesia. Some inference, as to the proportion of the magnesia, may be drawn from the intensity of the colour produced.

All these alkaline earths, when pure, are readily fusible with the fluxes, into a clear, colourless glass, without effervescence; but on adding a further quantity of the earth, the glass becomes opaque.

Alumina (1339) combines more slowly with the fluxes than the preceding earths, and forms a clear glass, which does not become opaque. But the most striking character of alumina is the bright blue colour it acquires from the addition of a drop of nitrate of cobalt, after having been dried and ignited for some time. It may thus be detected in compound minerals where the metallic substances are not in great proportion, nor the quantity of magnesia large.

The following, according to Berzelius, is a ready method of discovering *lithia* (609) in any mineral supposed to contain it; it is founded on the facility with which that alkali attacks platinum.

Take a morsel of the mineral, about the size of a pin's head, or a small quantity of it reduced to fine powder, and heat it with an excess of soda, on a slip of platinum foil before the blow-pipe, and keep it red hot for about two minutes. The stone will be decomposed, the soda will expel the lithia from its combination, and the excess of alkali, becoming fluid at this temperature, will spread over the surface of the foil, and envelope the decomposed mass. The platinum round the fused alkaline mass assumes a dark colour, deep and extensive in proportion to the quantity of lithia in the mineral. The platinum beneath the alkali is not oxidated, but only in those parts where it is in contact both with the air and the lithia. Potassa destroys the action of platinum on the lithia, if it be not in considerable quantity. The metal recovers its brilliancy after being well washed with water and heated to redness. —*Annales de Chimie*, Vol. x. p. 104, note.

Metallic Oxides and Acids.

Arsenic (1013) flies off accompanied by its characteristic smell, resembling garlic. When large pieces of white arsenic are heated on ignited charcoal, no smell is perceived. To produce this effect, the white oxide must be reduced by being mixed with powdered charcoal. If arsenic be suspected in a solution, it may be discovered by dipping into it a piece of pure and well-burnt charcoal, which is afterwards to be dried and ignited.

Chromium.—Its green oxide (1081) exhibits the following properties: it is fusible with microcosmic salt (phosphate of soda and ammonia) in the interior flame, into a glass which at the instant of its removal from the flame is of a violet hue, approaching more or less to dark blue or red, according to the proportion of the chromium. After cooling, the glass is bluish green, but less blue than copper glass. In the exterior flame the colour becomes brighter, and less blue than the former. With borax it forms a bright yellowish or yellow red glass in the exterior flame; and in the interior flame this becomes darker and greener, or bluish green.

Molybdic acid (1071) melts by itself upon the charcoal with ebullition, and is absorbed. In a platinum spoon it emits white fumes, and is reduced in the interior flame to molybdous acid, which is blue, but in the exterior flame it is again oxidated and becomes white. With microcosmic salt, in the exterior flame, a small proportion of the acid gives a green glass, which by gradual additions of the acid passes through yellow green to reddish, brownish, and hyacinth brown, with a slight tinge of green. In the interior flame the colour passes from yellow-green, through yellow-brown, and brown-red, to black; and if the proportion of acid be large, it acquires a metallic lustre, like the sulphuret, which sometimes remains after the glass has cooled. Molybdic acid is but sparingly dissolved by borax. In the exterior flame the glass acquires a grey-yellow colour. In the interior flame black particles are precipitated from the clear glass, leaving it almost colourless when the quantity of molybdenum is small, and blackish when the proportion is large. If to a glass formed of this acid and microcosmic salt a little borax be added, and the mixture fused in the exterior flame, the colour becomes instantly reddish-brown; in the interior flame, the black particles are also separated, but in smaller quantity. By long-continued heat the colour of the glass is diminished, and it appears yellower by the light of a lamp than by day-light. This acid is not reduced by soda in the interior flame.

Tungstic Acid (1095, p. 274.) becomes upon charcoal at first brownish yellow, is then reduced to a brown oxide, and lastly, becomes black without melting or smoking. With microcosmic salt it forms in the interior flame a pure blue glass, without any violet tinge; in the exterior flame this colour disappears, and appears again in the interior. With borax, in the internal flame, and in small proportion, it forms a colourless glass, which by increasing the proportion of acid, becomes dirty grey, and then reddish. By long exposure to the external flame it is rendered transparent, but as it cools it becomes muddy, whitish, and changeable into red when seen by day-light. It is not reduced.

Oxide of Columbium (1108, p. 276.) undergoes no change by itself, but is readily fused with microcosmic salt and with borax, into a clear colourless glass, from which the oxide may be precipitated by heating and cooling it alternately. The glass then becomes opaque, and the oxide is not reduced.

Oxide of Titanium (992) becomes yellowish when ignited in a spoon, and upon charcoal dark brown. With microcosmic salt it gives in the interior flame a fine violet-coloured glass, more tending to blue than that from manganese. In the exterior flame this colour disappears. With borax it gives a dirty hyacinth colour.

Oxide of Cerium (998) becomes red brown when ignited. When the proportion is small it forms with the fluxes a clear, colourless glass, which by increasing the proportion of oxide becomes yellowish-green while hot. With microcosmic salt, if heated a long time in the internal flame, it gives a clear colourless glass.

With borax, under similar circumstances, it gives a faint yellow-green glass while warm, but is colourless when cold. Exposed again for some time to the external flame, it becomes reddish yellow, which colour it partly retains when cold. If two transparent beads, one of the compound with microcosmic salt, the other with borax, be fused together, the triple compound becomes opaque and white. The oxide is volatile.—See *Thomson's Chemistry*, Vol. i. p. 408, *5th edition.*

Oxide of Uranium (983).—The yellow oxide by ignition becomes green or greenish brown. With microcosmic salt in the interior flame it forms a clear yellow glass, the colour of which becomes more intense when cold. If long exposed to the exterior flame, and frequently cooled, it gives a pale yellowish, red-brown glass, which becomes greenish as it cools. With borax in the interior flame, a clear, colourless, or faintly green glass is formed, containing black particles, which appear to be the metal in its lowest state of oxidation. In the exterior flame this black matter is dissolved if the quantity be not too great, and the glass becomes bright yellowish-green, and after further oxidation yellowish-brown. If brought again into the interior flame, the colour gradually changes to green, and the black matter is again precipitated, but no further reduction takes place.

Oxide of Manganese (703) gives with microcosmic salt, in the exterior flame, a fine amethyst colour, which disappears in the interior flame. With borax it gives a yellowish hyacinth red glass. When the manganese, from its combination with iron, or any other cause, does not produce a sufficiently intense colour in the glass, a little nitre may be added to it while in a state of fusion, and the glass then becomes dark violet while hot, and reddish violet when cool. It is not reduced.

Oxide of Tellurium (1002), when gently heated, becomes first yellow, then light red and afterwards black. It melts and is absorbed by the charcoal, and is reduced with a slight detonation, a greenish flame and a smell of horse-radish. Microcosmic salt dissolves it without being coloured.

Oxide of Antimony (907) is partly reduced in the exterior flame, and spreads a white smoke on the charcoal. In the interior flame it is readily reduced, either alone or with the addition of soda. With microcosmic salt and with borax it forms a hyacinth coloured glass. Metallic antimony, when ignited on charcoal, becomes covered with radiating acicular crystals of white oxide. Sulphuret of antimony melts on charcoal, and is absorbed.

Oxide of Bismuth (939) melts readily in a spoon to a brown glass, which becomes brighter as it cools. With microcosmic salt it forms a grey yellow glass, which loses its transparency, and becomes pale when cool. Add a further proportion of oxide, and it becomes opaque.

With borax it forms a grey glass, which decrepitates in the interior flame, and the metal is reduced and volatilized. It is readily reduced by itself on charcoal.

Oxide of Zinc (766) becomes yellow when heated, but whitens as it cools. A small proportion forms with microcosmic salt, and with borax a clear glass, which becomes opaque on increasing the quantity of oxide. A drop of nitrate of cobalt being added to the oxide and dried and ignited, it becomes green. With soda in the interior flame it is reduced, and burns with its characteristic flame, depositing its oxide upon the charcoal. By this process zinc may be easily detected even in the automalite. Mixed with oxide of copper, and reduced, the zinc will be fixed and brass obtained. But one of the most unequivocal characters of the oxide of zinc is, to dissolve it in vinegar, evaporate the solution to dryness, and expose it to the flame of a lamp when it will burn with its peculiar flame.

Oxide of Cadmium (819) is orange yellow, not volatile, and easily reduced; it gives no colour to borax.—*Annales de Chimie et Phys.*, Tom. viii., p. 100.

Oxide of Iron (722) produces with microcosmic salt, or borax in the exterior flame, when cold, a yellowish glass, which is blood-red while hot. The protoxide forms with these fluxes a green glass, which by increasing the proportion of the metal passes through bottle green to black, and is opaque. The glass from the peroxide becomes green in the interior flame, and is reduced to protoxide, and becomes attractable by the magnet. When placed on the wick of a candle, it burns with the crackling noise peculiar to iron.

Oxide of Cobalt (958) becomes black in the exterior, and grey in the interior flame; a small proportion forms with microcosmic salt and with borax a blue glass, that with borax being the deepest. By transmitted light the glass is reddish. By farther additions of the oxides, it passes through dark blue to black. The metal may be precipitated from the dark blue glass by inserting a steel wire into the mass while in fusion. It is malleable if the oxide has been free from arsenic, and may be collected by the magnet, and is distinguished from iron by the absence of any crackling sound when placed on the wick of a candle.

Oxide of Nickel (1112) becomes black at the extremity of the exterior flame, and in the interior greenish grey. It is dissolved readily, and in large quantity, by microcosmic salt. The glass while hot is a dirty dark red, which becomes paler and yellowish as it cools. After the glass has cooled, it requires a large addition of the oxide to produce a distinct change of colour. It is nearly the same in the exterior and interior flame, being slightly reddish in the latter. Nitre added to the bead makes it froth, and it becomes red brown at first and afterwards paler. It is easily fusible with borax, and the colour resembles the preceding. When this glass is long exposed to a high degree of heat in the interior flame, it passes from reddish to blackish and opaque, then blackish grey and transparent: then paler reddish grey, and clearer; and lastly, transparent, and the metal is precipitated in small white metallic globules.

The red colour seems here to be produced by the entire fusion or solution of the oxide, the black by incipient reduction, and the grey by the minute metallic particles before they combine and form small globules. When a little soda is added to the glass formed with borax, the reduction is more easily effected, and the metal collects itself into one single globule. When this oxide contains iron, the glass retains its own colour while hot, but assumes that of the iron as it cools.

Oxide of Tin (790), in form of hydrate, and in its highest degree of purity, becomes yellow when heated, then red, and when approaching to ignition black. If iron or lead be mixed with it, the colour is dark brown when heated. These colours become yellowish as the substance cools. Upon charcoal in the interior flame, it becomes and continues white; and if originally white, and free from water, it undergoes no change of colour by heating. It is very easily reduced without addition, but the reduction is promoted by adding a drop of solution of soda or potassa.

Oxide of Lead (872) melts, and is very quickly reduced, either without any addition, or when fused with microcosmic salt or borax. The glass not reduced is black.

Oxide of Copper (826) is not altered by the exterior flame, but becomes protoxide in the interior. With both microcosmic salt and borax it forms a yellow-green glass while hot, but which becomes blue-green as it cools. When strongly heated in the interior flame, it loses its colour, and the metal is reduced. If the quantity of oxide be so small that the colour be not preceptible, its presence may be detected by the addition of a little tin, which occasions a reduction of the oxide to protoxide, and produces an opaque red glass. If the oxide has been fused with borax, this colour is longer preserved; but if with microcosmic salt, it soon disappears by a continuance of heat. The copper may also be precipitated upon iron, but the glass must be first saturated with iron. Alkalies or lime promote this precipitation. If the glass containing copper be exposed to a smoky flame, the copper is superficially reduced, and the glass covered while hot with an iridescent pellicle, which is not always permanent after cooling. It is very easily reduced by soda. Salts of copper, when heated before the blow-pipe, give a fine green flame.

Oxide of Mercury, (1149) before the blow-pipe, becomes black and is entirely volatilized. In this manner its adulteration may be discovered.

The other metals may be reduced by themselves, and may be known by their own peculiar character.—*Thomson's Annals*, No. lxi. p. 42, et seq.

1374. Although the principal analyses in the following sections have been conducted in the laboratory of the Royal Institution, and are therefore the results of actual experiment, there are many difficulties in their performance, which practice alone will enable the student to overcome, and some fallacies, to which, even with extensive experience, he will still find himself liable: among the latter, I cannot help adverting to those attractions of the metallic oxides for each other, which have been but little studied, but which often present serious difficulties to the preceedings of the analyst; where, for instance, several earths are held in the same solution, it is extremely difficult to effect their complete separation by the agency of those precipitants, which are generally regarded as throwing down only one of them; in the same way, although water occasions no precipitate in permuriate of tin, but throws down the oxide from permuriate of antimony, yet if the permuriates be mixed, it is found that the precipitate by water contains a very notable proportion of peroxide of tin; and many similar cases might be adduced.

The practice of submitting substances of known composition to analysis, cannot be too strongly recommended to the chemical student; it makes him acquainted with the mutual actions and habitudes of a number of bodies, which experience can alone teach, and gives a dexterity of manipulation, and an accuracy in conducting experimental inquiries, of which he will find the value when subsequently in the pursuit of original investigations.

SECTION I. *Of the Compounds of Potassium.*

Characters.

1375. PURE POTASSA (544) should be perfectly soluble in twice its weight of water, and the solution should not effervesce upon the addition of a few drops of nitric acid, but remain undisturbed and transparent.

If nitric acid cause an effervescence in the solution of potassa, it indicates *carbonic acid;* if a precipitate not soluble in slight excess of the acid, it is *silica;* if a precipitate soluble in slight excess of acid, it is *alumina.*

The presence of *lime* in solution of caustic potassa, is shown by neutralizing it by nitric acid, filtering if necessary, and adding oxalate of ammonia, which causes a white cloud; or, by the production of a precipitate of carbonate of lime upon adding solution of bi-carbonate of potassa.

Baryta water should occasion no turbidness in a solution of pure potassa; if it occasion a precipitate soluble with effervescence in nitric acid, it announces *carbonic acid;* if insoluble, *sulphuric acid.*

1376. *Chlorate of Potassa* (546) is sometimes mixed with a little of the *chloride of potassium*, which is shown by the addition of solution of nitrate of silver occasioning a precipitate, which it does not in the solution of the pure chlorate.

1377. *Nitrate of Potassa* (551).—The quantity of pure nitre in a given portion of the rough salt may be learned with tolerable accuracy by the following process:

Purification of Nitre.—7 lbs. of rough nitre are accurately weighed, and then dissolved by heat in 21 parts of water; when boiling, the scum is removed until no more rises, and then the solution is allowed to settle for ten minutes or longer. In this way nearly all the dirt falls down, and the clear solution being poured off, is passed through a filter of tow into a pan, and set aside to crystallize; the dirt left behind is added to the scum, and both being diluted, are filtered through paper, and the clear solution preserved. Next day the crystals formed in the pan are separated and put into funnels to drain, and the mother liquor with the filtered solution from the scum, &c., are further evaporated and again left to crystallize. On the second evaporation, impurities generally separate from the solution; these are sometimes oxide of iron, or sulphate of lime, but most frequently common salt and nitrate of soda. The two first are easily separated by filtration; the third is best separated by evaporating the solution considerably, until much salt has been deposited, and then pouring the whole upon a filter of tow; the salt will remain on it, and should be washed by water to separate the nitre, which water should be added to the liquor, and the whole then brought to the crystallizing point. When cold, the crystals deposited by this solution are to be separated, and more salt separated as before, until the mother liquor is divided into common salt and nitre. It frequently happens that the crystals from the two or three last evaporations are coloured or contaminated by the adhesion of common salt, sulphate of lime, *&c.*; in this case, they should be re-dissolved and re-crystallized with the same precautions as before. Care should be taken in drying the crystals, especially when small or when hastily formed, that no water remain in the interstices or cleavages between them.

Solution of pure nitre is not rendered turbid either by nitrate of silver or nitrate of baryta.

1378. *Gunpowder.*—To analyse this compound, boil it with four parts of water, edulcorate the residue, dry it at 212°, and weigh; the loss indicates the nitre. The dry residue, composed of charcoal and sulphur, may be decomposed by spreading it upon an earthen plate and burning off the sulphur at the lowest possible heat; the charcoal will remain, still however retaining a little sulphur. A more accurate process consists in introducing the mixture into a small retort furnished with a stopcock, exhausted, and filled with chlorine; heat applied volatilizes the chloride of sulphur and leaves the charcoal, which may be washed, dried, and weighed.

1379. *Carbonate of Potassa.*—Dr. Henry has given the following directions for ascertaining the quantity of real alcali contained in the rough alcalis of commerce; the process depends upon their saturating power in respect to an acid of known density, and the principle of the analysis has been already adverted to (569, 600); his directions, however, are of such practical utility, that I have, with his permission, transcribed them. "Provide a tube, nine inches and a half long and three fourths of an inch internal diameter, provided with a lip for the convenience of pouring, and a glass foot to support it.

"A tube of this kind holds 1000 grains of water, and (which is desirable) a little more. To graduate it, weigh into it 100 succesive portions of distilled water at 60° Fahrenheit, of ten grains each; or, if the tube be of equal bore throughout, it may be sufficient to weigh into it ten successive portions of water of 100 grains each, dividing each of the intermediate spaces into ten parts by a pair of compasses. When 1000 grains of water have been weighed into the tube, a line may be drawn with a file, which may be marked 0, the tenth below this 10, and so on.

"The test acid, which I prefer, is made by diluting one part of oil of vitriol of commerce of sp. gr. 1.849, with four parts of water; consequently, one fifth part of its weight is concentrated oil of vitriol, and its specific gravity is, as nearly as possible, 1.141. Acid of this strength does not, on farther dilution, give out any heat, that can be a source of inaccuracy.

"When an alcali is to be examined, find, by Dr. Wollaston's Scale of Equivalents, how many grains of oil of vitriol are required to neutralize 100 grains of what may be considered the proper alcaline ingredient of the substance in question. This, in *pearlash*, is sub-carbonate of potash; in *potash*, pure potash; in *barilla* or *kelp*, dry sub-carbonate of soda. Let us take pearlash as an example. On referring to the scale, we find that 100 grains of sub-carbonate of potash are equivalent to 71 grains of concentrated oil of vitriol*. Put, therefore, into the test-tube a quantity of the dilute acid containing 71 grains of concentrated acid, *viz.*, 355 grains; and to spare the trouble, on any future occasion, of weighing the acid, let a line be drawn with a file on the blank side of the tube, at the level of the acid liquor, which may be marked *Equiv. of Subc. Pot.*

"Fill up the tube with water to the line marked 0, and mix the acid and water completely by pouring them into a lipped glass vessel; stirring with a glass rod; and then returning them into the tube. Now as the whole 100 measures contain a quantity of oil of vitriol equivalent to 100 grains of sub-carbonate of potash, it is obvious that each measure of the liquor in the tube is adequate to the neutralization of one grain of the sub-carbonate.

"Let 200 grains, taken out of a fair average specimen of the pearlash to be examined, be dissolved in two ounce measures of warm distilled water, filter the solution; and wash the filter with two ounces more of water, which is best applied to the margin of the paper, by means of a dropping bottle. Add the washings to the solution, and having mixed the whole together, pour one half into a tumbler or goblet, reserving the other half for a repetition of the experiment if necessary.

"To the liquor in the glass goblet, add the diluted acid very gradually, making the additions more and more slowly towards the last. As soon as the point of neutralization is attained, which will be shown by the cessation of a change of colour in slips of litmus and of turmeric paper dipped, from time to time, into the liquor, no more acid must be added. It is proper, however, the operator should be aware, that there will often be an apparent excess of test acid, in consequence of the carbonic acid, which is disengaged, acting on the litmus paper. To avoid this source of error, it is advisable, towards the last, to warm the liquor, by setting the glass containing it for half an hour near the fire, and while thus warmed, to add very cautiously the rest of the acid required for saturation. This point being attained, the number on the test-tube, at the level of the acid remaining in it, shows at once, without any calculation, how much *per cent.* of sub-carbonate of potash is contained in the pearlash under examination. In the samples I have tried, it has generally been about 80 *per cent.*

"In operating on barilla, kelp, or any variety of the mineral alcali, the process is exactly the same, except that as 93† of oil of vitriol are equivalent to 100 of sub-carbonate of soda, we must take $93 \times 5 = 465$ grains, of sulphuric acid of density 1.141. This may be marked on the tube, *Equivalent of Subcarbonate of Soda.* In a similar manner, we may mark on the tube the equivalent of *pure potash*, *viz.*, 520 grains of the above diluted acid; and that of *pure soda*, 783 grains; with any other equivalents, that may be likely to be of use.

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* Dr. Ure makes it 70.4.—*Journ. of Science.* iv. 119.

† According to Dr. Ure, 91.4 is the true equivalent.—*Journ. of Science, &c.* iv. 119.

"Having ascertained the proportion of sub-carbonate of potash in any sample of pearlash, it is easy to find, by the sliding scale, its equivalent quantity of pure or caustic potash. Thus, supposing the pearlash to contain 80 *per cent.* of sub-carbonate, that number being set to sub-carbonate of potash on the scale, the equivalent in pure potash is at once seen to be 55.

"To determine, by the same graduated tube, the strength of *any acid* whose equivalent is known, (which is the reverse of the foregoing process) we must put 100 grains of the acid, with a sufficient quantity of water, into a goblet; and use, for saturating it, its equivalent of any alcali. For example, 100 grains of concentrated oil of vitriol requiring for saturation 108 grains of dry sub-carbonate of soda, dissolve the latter quantity of alcali in water sufficient to make up 100 measures of solution in the tube; then pour the alcaline solution to the acid liquor, till the latter is neutralized; and the number of measures which have been expended, exactly denote the strength of the acid.

"It may sometimes be desirable to know the proportion, not of concentrated or of real acid, but of acid of some inferior degree of density, in a specimen of acid. The method of doing this will best be explained by an example. Suppose that we wish to know the equivalent, in muriatic acid of sp. gr. 1.160, to 100 grains of the same acid of sp. gr. 1.074; find, by the alcaline test, or by referring to the tables in the Appendix, how much real acid 100 grains of both those acids contain. In acid of sp. gr. 1.160 it will be 23.4 *per cent.*; in acid of sp. gr. 1.074, it will be 11. Then 23.4 : 100 : : 11 : 47. Therefore 47 grains of muriatic acid, of sp. gr. 1.160, are equivalent, in acidity, to 100 of sp. gr. 1.074.

"No chemical operation can be more simple, or more easily managed, than the measurement of the strength of alcalis by acid liquors, and of acids by alcaline ones, in the way which has been described. The test-tube, which is the only instrument, required for that purpose, may be had at any glass-house, and may easily be graduated by any person who will take the necessary pains. When once accurately prepared, it will be found, also. useful for a variety of other purposes, which will readily present themselves to the practical chemist."

1380. The *purified Carbonate of Potassa* (569) of the shops should be perfectly soluble in twice its weight of cold water. It often contains *silica*, *sulphate of potassa*, *chloride of potassium*, and *carbonate of lime*. To detect these, dissolve a hundred grains in nitric acid diluted with eight parts of water: the silica, if any be present, remains undissolved: separate the solution into three equal parts; to the first, add nitrate of baryta, which causes a precipitate of sulphate; collect, wash, and dry it; 100 parts are equivalent to 74 of sulphate of potassa: to the second, add nitrate of silver; 100 grains of the precipitate, washed and dried at a dull red heat, is equivalent to 52 of chloride of potassium: to the third, add oxalate of ammonia, and dry the edulcorated precipitate at a heat of 300°; 100 parts are equal to 77 of carbonate of lime.

1381. There are a few mineral substances which contain potassa; it was first detected in the *leucite* by Klaproth, whose analysis of that mineral may be advantageously consulted by the student. (*Analytical Essays*, i. 348.) It consists of

Silica	53.750
Alumina	24.625
Potassa	21.350
	99.725

There are two modes of analysis which may be practised upon such minerals; they may either be directly acted upon by acids: or fused with baryta, and afterwards submitted to acid solution.

A. 100 grains of leucite in very fine powder were digested for six hours in muriatic acid, which was then decanted off and the residue washed upon a filter, the washings being mixed with the solution. The residue weighed 60 grains. (*a*,)

B. The muriatic solution was supersaturated with pure ammonia, which occasioned a bulky brownish precipitate (*b*), which was collected, washed, and dried; it amounted to 12.5 grains.

C. Carbonate of ammonia produced no change in the last-mentioned. filtrated liquor, which was therefore evaporated to dryness and the residue exposed to a red heat in a platinum crucible; it was then completely re-dissolved in water and again evaporated to dryness; it had the characters of chloride of potassium (*c*), and weighed 41 grains.

D. The residue *a* A was fused with three parts of potassa in a silver crucible, the fused mass dissolved in water, supersaturated *with* muriatic acid, evaporated to dryness, and again digested in water; there remained 58.5 grains of dry and pure silica.

E. The precipitate *b* B was entirely soluble in pure solution of potassa, with the exception of a trace of oxide of iron. Being again thrown down by muriate of ammonia, it was found to be pure alumina.

F. The chloride of potassium *c* C was decomposed in a platinum crucible by sulphuric acid, and it afforded 48 grains of sulphate of potassa, which is eqivalent to 26 of potassa.

The result of this analysis differs in the proportions of the components from that of Klaproth; it may be stated as follows:

Silica, A *a*	58.5 grains
Alumina with a trace of iron } B *b* & E . . .	12.5
Potassa, C *c* F	26.
Loss	3.
	100.

1382. It may here be remarked, that the existence of potassa, soda, and lithia in minerals, is generally first indicated by the great apparent loss which is sustained upon collecting and weighing their precipitable components: thus, if in any case of analysis we lose upon the aggregate weight of the precipitates, more than 2 or 3 *per cent.*, we may suspect the existence of the fixed alcalis, and direct our attention accordingly to their detection. It also generally happens, that minerals which contain any considerable proportion of fixed alcaline substances, are remarkable for the facility with which they enter into fusion before the blow-pipe,

SECTION II. *Of the Combinations of Sodium.*

To distinguish soda from potassa.

1383. *Pure Soda* (577) may be tested in the same way as pure potassa. The presence of *potassa* in soda may be detected by adding to its aqueous solution muriate of platinum, which forms a buff-coloured precipitate if potassa be present.

To purify.

1384. *Chloride of Sodium.* (579). The usual impurities of sea salt are *muriates of magnesia and lime.* Dissolve 100 grains in an ounce of water, and add carbonate of ammonia, which throws down carbonate of lime, 100 parts of which, washed and dried at 300°, are equivalent to 110 of dry muriate of lime (chloride of calcium). Boil the filtered liquor nearly to dryness, and carbonate of magnesia falls, of which 100 parts are equal to about 134 of dry muriate of magnesia.

Analysis of.

1385, *Sulphate of Soda.*—This salt in the form of crystals, may be analyzed as follows: Weigh off 100 grains, and introduce it into a platinum crucible, previously weighed; place it in a sand heat, and gradually give it a red heat for half an hour; when cold ascertain the loss of weight, which is water of crystallization. (*a*). Pour two ounces of water upon the dry salt, and when perfectly dissolved add solution of nitrate of baryta as long as it occasions any precipitate; edulcorate, dry, and weigh the sulphate of baryta thrown down (*b*), of which 100 parts indicate 34 of sulphuric acid. The filtered liquor contains the soda, now in the state of nitrate, and any excess of nitrate of baryta that might have been added: evaporate it to dryness, expose the residue to a red heat for half an hour in a platinum crucible, by which the acid will be expelled, and a mixture of soda and baryta remain; pour upon it dilute sulphuric acid, which forms sulphate of soda and sulphate of baryta; the latter, being insoluble, is separated by filtration; the filtered solution of regenerated sulphate of soda should afford on evaporation and expulsion of water as above directed, a quantity of sulphate, exactly equal to that of the process. (*a*). Thus it will be found that 100 grains of sulphate of soda in crystals, afford of

Water	56.00
Sulphuric acid	24.75
Soda	19.25

1386. Sulphate of soda is seldom sophisticated; it should not change the colour of litmus or turmeric; it sometimes contains a little iron, which interferes with some of its pharmaceutical uses; this may be detected by adding tincture of galls to the aqueous solution of the salt, slightly acidulated by nitric acid, when it occasions a black cloud. Sea salt is discovered in solution of sulphate of soda, by the addition of sulphate of silver; salts of lime are shown by the precipitate of carbonate of lime, occasioned by carbonate of ammonia. Sulphate of potassa is recognised by its sparing solubility.

1387. *Carbonate of Soda.*—The analysis of kelp and barilla has been above referred to. (page 338.)

Analysis of.

The carbonate of soda of the shops (*sodæ subcarbonas* of the *Pharmacopæia*), often contains *sulphate of soda* and *sea salt;* to discover these, saturate a given weight of the salt with pure dilute nitric acid, and divide the solution into two parts: to one add nitrate of baryta, which gives a precipitate of sulphate of baryta; to the other add nitrate of silver, which throws down chloride of silver, of which 100 parts, properly washed and dried, are equal to 41 of sea salt.

If carbonate of soda contain *carbonate of potassa*, its presence is shown by adding to a saturated solution of the carbonate, a saturated solution of tartaric acid *in excess;* a precipitation of crystalline grains of bi-tartrate of potassa ensues if potassa be present.

1388. *Bi-carbonate of Soda* is frequently mixed with carbonate of soda; and it is difficult to detect the proportion of the latter, in consequence of the quantity of water in the bi-carbonate, not having been accurately ascertained. The composition of the dry bi-carbonate is given above. (601).

1389. *Borate of Soda*, or borax, is sometimes adulterated by common salt, and by alum. To detect these, dissolve a portion of the salt in water, and add slight excess of nitric acid. Test this solution by nitrate of silver for the discovery of sea salt; and by nitrate of baryta for sulphuric acid.

1390. There are several minerals which contain soda; the following analysis of the sodalite, by Dr. Thomson, may be taken as an instance of one mode of proceeding in these cases.—*Phil. Mag.*, xxxvii. p. 303; or, *Transactions of the Royal Society of Edinburgh.*

"100 grains of the mineral, reduced to a fine powder, were mixed with 200 grains of pure soda, and exposed for an hour to a strong red heat in a platinum crucible. The mixture melted, and assumed, when cold, a beautifiul grass-green colour. When softened with water, the portion adhering to the sides of the crucible, acquired a fine brownish yellow. Nitric acid being poured upon it, a complete solution was obtained. Suspecting from the appearance which the fused mass assumed, that it might contain chromium, I neutralized the solution as nearly as possible with ammonia, and then poured into it a recently prepared nitrate of mercury. A white precipitate fell, which being dried and exposed to a heat rather under redness, was all dissipated, except a small portion of grey matter, not weighing quite 0.1 grain. This matter was insoluble in acids, but became white. With potash it fused into a colourless glass. Hence I consider it as silica. This experiment shows that no chromium was present. I was at a loss to account for the precipitate thrown down by the nitrate of mercury. But Mr. Allan having shown me a letter from Ekeberg, in which he mentions that he had detected muriatic acid in sodalite, it was easy to see that the whole precipitate was calomel. The white powder weighed 26 grains, indicating, according to the analysis of Chenevix, about 3 grains of muriatic acid.

"The solution, thus freed from muriatic acid, being concentrated by evaporation, gelatinized. It was evaporated nearly to dryness, the dry mass digested in hot water, acidulated with nitric acid, and poured upon the filter, was washed, dried, and heated to redness. It weighed 37.2 grains, and was silica. The liquor which had passed through the filter was supersaturated with carbonate of potash, and the copious white precipitate which fell, collected by the filter, and boiled, while yet moist, in potash-ley. The bulk diminished greatly, and the undissolved portion assumed a black colour, owing to some oxide of mercury with which it was contaminated. The potash-ley being passed through the filter, to free it from the undissolved matter, was mixed with a sufficient quantity of sal-ammoniac. A copious white precipitate fell, which being collected, washed, dried, and heated to redness, weighed 27.7 grains. This powder being digested in sulphuric acid, dissolved except 0.22 grain of silica. Sulphate of potash being added, and the solution set aside, it yielded alum crystals to the very last drop. Hence the 27.48 grains of dissolved powder were alumina.

" The black residue, which the potash-ley had not taken up, was dissolved in diluted sulphuric acid. The solution being evaporated to dryness, and the residue digested in hot water, a white soft powder remained, which, heated to redness, weighed 3.6 grains, and was sulphate of lime, equivalent to about 2 grains of lime.

" The liquid from which the sulphate of lime was separated, being exactly neutralized by ammonia, succinate of ammonia was dropped in, a brownish red precipitate fell, which being heated to redness in a covered crucible, weighed 1 grain, and was black oxide of iron.

" The residual liquor being now examined by different re-agents, nothing further could be precipitated from it. The liquid from which the alumina, lime, and iron, had been separated by carbonate of potash, being boiled for some time, let fall a small quantity of yellow coloured matter. This matter being digested in diluted sulphuric acid, partly dissolved with effervescence, but a portion remained undissolved, weighing 1 grain. It was insoluble in acids, and with potash melted into a colourless glass. It was therefore silica. The sulphuric acid solution being evaporated to dryness, left a residue which possessed the properties of sulphate of lime, and which weighed 1.2 grains, equivalent to about 0.7 grain of lime.

" The constituents obtained by the preceding analysis being obviously defective, it remained to examine whether the mineral, according to the conjecture of Bournon, contained an alcali. For this purpose 100 grains of it, reduced to a fine powder, and mixed with 500 grains of nitrate of barytes, were exposed for an hour to a red heat in a porcelain crucible. The fused mass was softened with water, and heated with muriatic acid. The whole dissolved except 25 grains of a white powder, which proved on examination to be silica. The muriatic acid solution was mixed with sulphuric acid, evaporated to dryness, the residue digested in hot water, and filtered to separate the sulphate of barytes. The liquid was now mixed with an excess of carbonate of ammonia, boiled for an instant or two, and then filtered, to separate the earth and iron precipitated by the ammonia. The liquid was evaporated to dryness, and the dry mass obtained exposed to a red heat in a silver crucible. The residue was dissolved in water, and exposed in the open air to spontaneous evaporation. The whole gradually shot into regular crystals of sulphate of soda. This salt being exposed to a strong red heat, weighed 50 grains, indicating, according Berthollet's late analysis, 23.5 grains of pure soda. It deserves to be mentioned, that during this process the silver crucible was acted on, and a small portion of it was afterwards found among the sulphate of soda.

" This portion was separated before the sulphate of soda was weighed.

" The preceeding analysis gives us the constituents of sodalite as follows:

Silica	38.52
Alumina	27.48
Lime	2.70
Oxide of iron	1.00
Soda	23.50
Muriatic acid	3.00
Volatile matter	2.10
Loss	1.70
	100.00

"Mr. Allan sent a specimen of this mineral to Mr. Ekeberg, who analyzed it in the course of last summer. The constituents which he obtained, as he states them in a letter to Mr. Allan, are as follows:

Silica	36.
Alumina	32.
Soda	25.
Muriatic acid	6.75
Oxide of iron	0.25
	100.00

"This result does not differ much from mine. The quantity of muriatic acid is much greater than mine. The lime and the volatile matter which I obtained escaped his notice altogether. If we were to add them to the alumina it would make the two analyses almost the same. No mineral has hitherto been found containing nearly so much soda as this. Hence the reason of the name by which I have distinguished it."

SECTION III. *Of the Combinations of Lithium.*

1391. LITHIUM (607) has been found in a very few minerals only. It is contained in largest quantity in the *triphane* or *spodumene*, which consists of

Silica	66.
Alumina	25.
Lithia	9.
A trace of oxide of iron.	
	100.

Triphane has been found in Sweden, in the Tyrol, and in Ireland. Its colour is greyish green; it is translucent, hard, and brittle: specific gravity 3.2. It occurs massive, and its structure is lamellar, and fibrous.

Petalite, according to the corrected analysis of M. Arfwedson, consists of

Silica	77.
Alumina	17.
Lithia	6.
	100.

Petalite has hitherto been found in Sweden only: its colours are reddish, greenish, or grayish white. It is translucent, lamellar, and hard: specific gravity 2.6.

1392. These minerals may be analyzed by the following process:

Analysis.

Reduce 50 grains, in an agate or steel mortar, to a very fine and impalpable powder, and mix it with thrice its weight of precipitated carbonate of baryta; give the mixture a red heat for an hour in a silver crucible, wash out the contents, add a small excess of muriatic acid, and evaporate to dryness; boil the dry residue in 12 parts of water, and filter when cold; the silica will remain on the filter, and may be washed, ignited, and weighed.

The filtered liquor (*a*) holds the muriates of baryta, alumina, iron, and lithia: add solution of sulphate of ammonia as long as it occasions a precipitate, which separate, and wash, adding the washings to the filtered liquor (*b*); the baryta is thus removed in the state of sulphate.

To the filtered solution (*b*) add carbonate of ammonia, to throw down the alumina and iron, which collect, and wash, adding the washings, to the third filtered liquor (*c*). The mixed precipitate of alumina and oxide of iron may be digested in potassa, which takes up the former, leaving the oxide of iron to be collected, washed, ignited, and weighed.

Evaporate the filtered solution (*c*) to dryness, and ignite the residuum in a silver crucible; the ammoniacal salts are driven off, and pure chloride of lithium remains, from which the lithia may be obtained by carbonate of silver, as above stated (607).

Section IV. *Of the Combinations of Calcium.*

1393. For the manufacture of mortar, lime should be entirely free from carbonic acid, the presence of which is ascertained by the effervescence occasioned on adding muriatic acid to a portion of the lime slaked in, and diffused through, water.

Quantity of carbonic acid.

1394. To ascertain the quantity of carbonic acid in carbonate of lime, or other carbonate, proceed as follows: Provide a thin light phial, capable of holding about six ounces, with a mouth of half an inch diameter: pour into this phial one ounce of nitric acid, diluted with its bulk of water, taking care not to soil the neck; stop it with a plug of cotton wool, and counter-balance the whole in the scale of a delicate beam. Having now weighed off 100 grains of the carbonate, place a hundred grain weight in the scale with the counterpoise, and carefully introduce the carbonate, broken into pieces, into the acid; stop the phial loosely with the wool, and suffer the carbonate to dissolve; during this operation the carbonic acid will escape through the cotton plug, which prevents any particles of liquid being thrown out during the effervescence, and the counterpoise scale will preponderate in consequence of the loss of weight sustained by the carbonate from the evolution of its carbonic acid. When the solution is complete, open the phial, and blow through it by a glass tube, so as to displace the included atmosphere; replace the plug, and bring the balance to an equipoise by adding weights to the scale containing the phial, which weights will show the quantity of carbonic acid lost by 100 grains of the carbonate. If pure carbonate of lime be employed, the loss will amount to 44 grains.

1395. We will suppose, however, that a limestone has been operated on not perfectly soluble in the acid, and containing magnesia and alumina; the other steps of the analysis are as follow:

The insoluble portion must be separated by decantation, collected upon a filter, washed and dried, the washings being added to the original solution. It is probably silica.

The solution we will suppose to contain lime, magnesia, and alumina; to separate these earths, add carbonate of potassa in very slight excess; boil the mixture, collect and wash the precipitate, which will consist of the carbonates of lime and magnesia, and alumina; digest it while moist in solution of pure potassa, which dissolves out the alumina; pour the whole upon a filter, washing the insoluble portion and add to the filtered liquid (which is the alcaline solution of alumina) a slight excess of oxalic acid; collect, wash, and dry the precipitate, at a red heat, in a platinum crucible, and weigh it; it is pure alumina. The separation of the magnesia and lime may be effected by the process above described (699).

1396. The analysis of *sulphate of lime* (633) may be effected by an alcaline carbonate as follows:

Analysis of sulphate of lime.

Reduce 50 grains of the sulphate to a very fine powder, and boil it for half an hour in a Florence flask, with 100 grains of carbonate of soda, dissolved in four ounces of water; the lime will thus be converted into carbonate, which, collected upon a filter, washed, and dried at 500°, will give either by inference, or analysis, the proportion of lime.

The filtered solution will contain the sulphuric acid of the sulphate, the quantity of which may be learned by adding muriate of baryta, and digesting the precipitate in dilute muriatic acid, to remove any carbonate of baryta; the insoluble residuum, washed and duly dried, gives the equivalent of the sulphuric acid.

The proportion of water of crystallization in the sulphates of lime, may be arrived at by exposing 100 parts in fine powder, to a red heat; the loss indicates the quantity of water *per cent.*

1397. The analysis of a mixture of carbonate and phosphate of lime may be performed in the following manner:

Dissolve in dilute nitric acid, and add pure ammonia to the solution, which causes a precipitate of phosphate of lime, equivalent, when dry, to that existing in the original mixture.

Having separated the phosphate by filtration, add carbonate of ammonia, which throws down carbonate of lime; collect, wash, and dry it.

1398. It is generally supposed that the quantity of acid and of base in phosphate of lime may be learned by the following process: Dissolve 50 grains of the phosphate in as small a quantity as will take it up of nitric acid, diluted with its bulk of water: to this solution add oxalate of ammonia, which will cause a precipitate of oxalate of lime, which may be separated, ignited to whiteness, and weighed; it gives the pure lime.

Phosphate of ammonia is retained in the solution, which, evaporated to dryness, and heated red hot in a platinum crucible, gives pure phosphoric acid: or, the solution may be decomposed by the addition of nitrate of lead; which gives an insoluble phosphate of lead, of which 100 parts indicate about 20 of phosphoric acid. But phosphate of lime is only partially decomposed by oxalate of ammonia and nitrate of lead. Phosphate of lime boiled with carbonate of potassa, gives rise to the production of carbonate of lime and phosphate of potassa.

1399. No accurate analysis has hitherto been made of *fluor spar* (646); and we are ignorant of the nature of the colouring principle of the blue variety; it fades by exposure to light, and is destroyed by a heat below redness.

When 100 grains of pure and colourless fluor spar, previously heated red hot, are boiled to dryness in a silver crucible, with 200 of sulpuric acid, and the dry mass exposed to a red heat, 190 parts of dry sulphate of lime are obtained, equivalent to about 78 of lime. If we regard fluor spar as a fluoride of calcium, the 78 of lime being equivalent to 56 of calcium, would give the composition of that substance

56 calcium
44 fluorine

and 56 : 44 : : 20 : 15.7. Upon this datum the number 16 has been above adopted as the representative of fluorine.

1400. The number 28., as the equivalent of lime, is that given by Dr. Wollaston in his valuable observations upon the synoptic scale of chemical equivalents, and regarding it as containing one third the quantity of oxygen existing in the proportion of sulphuric acid that combines with it to form sulphate of lime, the number 20 may be regarded as the correct equivalent of calcium.

Section V. *Of the Compounds of Barium.*

1401. By dissolving 100 grains of *native carbonate of baryta* (648), previously dried at a red heat, in muriatic acid, with the precautions above-directed (1393), they will be found to lose 22 grains of carbonic acid; hence the carbonate consists of

Baryta	78
Carbonic acid	22
	100

If we now precipitate the muriatic solution by carbonate of ammonia, collect the precipitate and dry it at a dull red heat, we shall find it to weigh 100 grains, showing that the composition of the native and artificial carbonate is similar.

If we precipitate the muriatic solution by dilute sulphuric acid, the precipitate of sulphate of baryta properly dried weighs 118 grains; hence the artificial sulphate is composed of

Baryta.	78	=	66
Sulphuric acid . . .	40		34
	118		100

100 grains of carbonate of baryta dissolved in nitric acid, evaporated to dryness, and exposed for half an hour to a red heat, gave 78 grains of pure baryta.

1402. These results, which closely agree with the original analyses of Dr. Withering (*Phil. Trans.*, 1784), and of Klaproth, (*Analytical Essays*, i.) furnish the number 78. as the representative of baryta, for in respect to the sulphate, 40 : 78 : : 40 : 78. The number 78. above adopted as the equivalent of baryta, is the mean of three analyses, and probably very near perfect correctness. Deducting from this number one third of the weight of the oxygen in sulphuric acid = 8 gives 70 as the theoretical equivalent of barium.

1403. The only compound mineral hitherto discovered containing baryta, is the harmotome or cross-stone; in that from Andreasberg, Klaproth found

Silica	49
Alumina	16
Baryta	18
Water	15
	98

The analysis of this compound may be made by fusing it in fine powder with potassa, solution in muriatic acid, and evaporation to dryness; pour water upon the dry mass, which leaves silica; to the solution add sulphate of ammonia, which throws down the baryta in the state of sulphate; separate it by a filter, evaporate the filtered liquor to dryness, and give it a red heat; re-dissolve the dry residue in water, and add ammonia, which throws down alumina.

◆

SECTION VI. *Of the Compounds of Strontium.*

1404. The analysis of the *sulphate* and *carbonate of strontia* may be performed in the same way as that of the corresponding compounds of baryta.

1405. Strontia has been found by Mr. Stromeyer in some varieties of *arragonite* (643), and where it exists in small proportion with carbonate of lime, its presence is not easily detected.

I dissolved 5 grains of carbonate of strontia and 95 of carbonate of lime in nitric acid; added sulphate of ammonia to the solution, collected the precipitate, and washed it with repeated affusions of hot water; when dry, it weighed 6.3 grains, and was sulphate of strontia. Ignited with half its weight of charcoal, and digested in dilute muriatic acid, it afforded a solution of muriate of strontia, the properties of which are easily distinguished from those of muriate of baryta (669).

1406. The number 44.0 as the equivalent of strontium, and 52 as that of strontia, are deduced from the analyses of the sulphate and of the carbonate.

SECTION VII. *Of the Compounds of Magnesium.*

1407. WHEN 100 parts of pure *crystallized sulphate of magnesia* are exposed to a red heat for one hour, they lose, upon the average of several experiments, 52 *per cent.* of water of crystallization; the residue is perfectly soluble in water, and consequently no acid has been expelled; if to its aqueous solution we add muriate of baryta, and collect and dry the precipitate, it will be found to indicate 32.5 of sulphuric acid; hence the composition of the crystallized salt; and

32.7 : 16.3 :: 40 : 19.9

Hence the number 20. adopted as the representative of magnesia, and 12. as the theoretical equivalent of its metallic base.

1408. Besides the adulteration of sulphate of magnesia with sulphate of soda, already adverted to, the salt as it occurs in commerce is often deliquescent from the presence of muriate of lime, and muriate of magnesia: the presence of muriatic acid is shown by sulphate of silver; and of lime, by oxalate of ammonia, or by bi-carbonate of ammonia, which does not throw down magnesia. Sea salt is not unfrequently found in considerable proportion, mixed with sulphate of magnesia, and which is not thus rendered deliquescent: it is recognised by its salt taste, by the action of sulphate of silver, and by pouring sulphuric acid upon it, which disengages muriatic vapours, easily known by the dense white fumes occasioned by holding a stopper moistened with liquid ammonia above the salt.

I have sometimes found amongst Epsom salt a very considerable proportion of the triple sulphate of magnesia and potassa. (687.) It is known by its sparing solubility, and by the rhomboidal form of its crystals: it occasions a grittiness in the mouth, and is less bitter than subphate of magnesia.

1409. *Carbonate of magnesia* (693), when precipitated in the usual way and dried at 212°, always retains a portion of water, which it loses by exposure to a red heat along with its carbonic acid; the water thus retained varies from 16 to 21 *per cent.* Lime is a very common impurity both in carbonate and calcined magnesia, being frequently derived from sulphate of lime contained in the water used for edulcorating the precipitated carbonate. To the calcined magnesia it gives an acrid alcaline taste. The presence of lime is detected by dissolving the magnesia or its carbonate in muriatic acid, and adding solution of bi-carbonate of ammonia, which throws down carbonate of lime, but does not affect a pure magnesian solution. When carbonate of lime is fraudulently added to carbonate of magnesia, as is sometimes the case, it is detected in the same way.

The separation of lime and magnesia, when present in the same solution, has already been adverted to (699).

1410. The analysis of mineral substances containing magnesia may in some cases be performed in the humid way; but where the stone resists the action of acids, fusion with alcaline bodies must be resorted to. As instances of these analyses, the reader is referred to Klaproth's examination of the chrysolite and of olivin, in the seventh and eighth Analysis of magnesian minerals.

sections of the first volume of his *Analytical Essays*. The following instances may serve further to illustrate the separation of magnesia in cases of complex chemical analysis.

A. 100 parts of red and green-veined primitive *serpentine* were exposed to a dull red heat for half an hour, and were found to have lost 6 grains.

B. The remaining 94 grains, reduced to fine powder, were digested in muriatic acid diluted with two parts of water, and when it no longer acted upon the residue it was decanted off, the residue washed, and the washings added to the muriatic solution. The undissolved portion, when dried at a red heat, weighed 38 grains, and had the properties of pure silica.

C. The muriatic solution supersaturated with liquid bi-carbonate of ammonia afforded a brown precipitate, which was collected, washed, and dried; it weighed 25.5 grains, and was found to contain no alumina; it dissolved entirely and with effervescence in muriatic acid, and this solution was evaporated to dryness, the dry residue dissolved in water, and this solution precipitated by oxalate of ammonia, yielded oxalate of lime, which collected and ignited to whiteness afforded 13 grains of pure lime: the liquor from which this oxalic precipitate had been obtained left after evaporation and ignition 2.5 grains of red oxide of iron, equivalent to about 2.2 grains of the black oxide, in which state the metal probably exists in serpentine.

D. The solution from which the precipitate noticed in the last paragraph had been separated, was next evaporated to dryness, and the residue exposed to a red heat in a platinum capsule, till it ceased to lose weight; in this way 40 grains of magnesia slightly tinged by an inappreciable portion of oxide of iron were obtained.

E. It accordingly appears from the above analysis, that 100 parts of precious serpentine contain.

A.	Water	6. grains
B.	Silica	38.
C.	Lime	13.
	Oxide of Iron	2.2
D.	Magnesia	40.
	Loss	.8
		100

Another specimen of serpentine, from the Lizard, lost 7 grains of water by heat; (*a*) digested in muriatic acid, it gave 43.5 grains of silica; (*b*) the muriatic solution was saturated with carbonate of ammonia, filtered and evaporated to dryness; the dry residue, after having been heated red-hot, gave 30.7 grains of magnesia; (*c*) upon the filter there remained a precipitate of a brown colour, which was dissolved in muriatic acid; pure ammonia added to this solution, gave a precipitate weighing 13 grains, and resolved by potassa into 10 grains of peroxide of iron = 9 protoxide, and 3 grains of alumina. (*d*) The muriatic solution, after the separation of the precipitate by pure ammonia, gave, on adding carbonate of ammonia, 5.3 grains of carbonate of lime = 3 grains of lime. This specimen, therefore, of serpentine, was composed of

	Water	7.0
a	Silica	43.5
b	Magnesia	30.7
c	Oxide of Iron	9.0
c	Alumina	3.0
d	Lime	3.0
		96.2

1411. There are some magnesian stones, such for instance as the chrysolite and the olivin, which are so hard as to resist to a considerable extent, even when pulverized, the action of muriatic acid: in conducting their analysis, they should be previously fused with potassa. If alumina be present, it may be thrown down from the muriatic solution together with the lime, by carbonate of ammonia, and afterwards separated by the action of solution of potassa.

Section VIII. *Of the Compounds of Manganese.*

1412. The *grey radiated ore of manganese* (703), when digested in fine powder in muriatic acid, is entirely dissolved, with the exception of a small but variable portion of silica, not exceeding 3 to 4 *per cent.*

The solution contains manganese with a small quantity of iron, which may be very conveniently separated by the action of ammonia, as recommended by Mr. Hatchett, and which, if added so as to saturate the muriatic acid, throws down the iron, but not the manganese.

The oxide of iron may be separated by filtration, and ignited with a little wax, which, when burned off, leaves protoxide of iron.

The filtered solution may be evaporated to dryness, and the residue moistened with nitric acid, and again evaporated and ignited: it is peroxide of manganese, the state probably in which the metal exists in the above ore.

1413. Manganese, as has been shown by Mr. Faraday, (*Quarterly Journal*, vi. 357,) readily forms triple salts with ammonia, and as these salts are not affected by the fixed alcalis, they are often conveniently formed in those analytical operations the object of which is to separate manganese from other metals: Upon this principle he proposes the following method of decomposing a mixed salt of manganese and iron. To a mixed solution of iron and manganese, add solution of muriate, sulphate, or nitrate of ammonia, and then pour in pure potassa; the iron will be precipitated immediately; but the manganese will remain in solution as a triple salt, unaffected by the free alcalis.

In this method of analysis the muriate or sulphate of ammonia is preferable to the nitrate, because the latter may in some cases produce peroxide of manganese, which would be precipitated; the quantity of ammoniacal salt added should, for the sake of security, be about twice that of the salt of manganese in solution, and as protoxide of iron is soluble in ammonia, any excess of that alcali should be driven off by heat, to ensure a total precipitation.

1414. The black oxide of manganese, as it occurs in commerce, is very often adulterated with chalk, which is detected by digesting a given weight of it in nitric acid diluted with 10 parts of water; if the oxide be pure, the acid thus diluted is without any immediate action; if it contain carbonate of lime, an instant effervescence ensues, and a nitrate of lime is formed, which may afterwards be decomposed by carbonate of potassa, and the weight of the precipitate when dry shows the quantity of the carbonate present.

SECTION IX. *Of the Compounds of Iron.*

Assay of iron ore.

1415. THE assay of those native oxides of iron which are the sources of the pure metal, may be performed as follows: reduce the ore to a very fine powder, and mix it with its weight of powdered green-bottle glass, half its weight of chalk, and one fourth of charcoal; expose this mixture to the full heat of a wind furnace for about an hour; suffer the crucible to cool slowly, and on breaking it, a button of metal will be found at the bottom, covered by the other materials, fused into a dense slag. If the ore contain any mixed pyrites, it should be previously roasted in a muffle or reverberatory furnace.

1416. The analysis of the *magnetic*, *specular*, and *hæmatitic oxides of iron* (725) is sufficiently simple, and may be accomplished in the following manner:

a. Reduce the ore to a very fine powder, and mix it in a silver crucible with three or four parts of liquid potassa; evaporate to dryness, and expose the residue for about 15 minutes to a dull red heat; when cold, reduce it to powder and dissolve in muriatic acid, evaporate nearly to dryness, and boil the residue in water; the silica remains, and may be separated by filtration. (*b*) The filtered solution of permuriate of iron may now be evaporated to a small bulk, and decomposed by potassa, which added in excess and boiled upon the precipitate, leaves peroxide of iron, and which having been washed, dried, and ignited with wax, is restored to the state of protoxide. (*c*) The filtered alcaline liquor now retains alumina, if any were present, which may be thrown down by muriate of ammonia, washed, and dried.

It sometimes happens that manganese is present in the muriatic solution *b*, and that it is thrown down with the oxide of iron: if this be the case, re-dissolve the precipitate, after its treatment by alcali, in muriatic acid, and *neutralize* by ammonia, which throws down the oxide of iron, but retains that of manganese; then proceed as directed in paragraph 1405.

1417. *Chloride of Iron* (727) was analyzed as follows: (*a*) 100 grains were dissolved in water, and the solution decomposed by ammonia afforded a precipitate, which when washed, dried, and ignited with wax, was black oxide of iron, weighing 56.5 grains, and equivalent to 44 grains of metallic iron. (*b*) The filtered solution from which the oxide of iron had been separated was neutralized by nitric acid; nitrate of silver was then added, and the precipitated chloride of silver being collected and ignited weighed 227 grains, which is equivalent to

56 grains of chlorine; hence it appears that protochloride of iron consists of

44	iron
56	chlorine
100	

By a similar process, the perchloride of iron may also be analyzed.

1418. The native sulphuret of iron, or *magnetic pyrites* (737), was examined by Mr. Hatchett in the following way (*Phil. Trans.*, 1804):

A. 100 grains, reduced to a fine powder, were digested with 2 ounces of muriatic acid, in a glass matrass placed in a sand-bath. A pale yellowish-green solution was formed. The residuum was then again digested with two parts of muriatic acid, mixed with one of nitric acid; and a quantity of pure sulphur was obtained, which, being dried, weighed 14 grains.

B. The acid in which the residuum had been digested, was added to the first muriatic solution; some nitric acid was also poured in, to promote the oxidizement of the iron, and thereby to facilitate the precipitation of it by ammonia, which was added after the liquor had been boiled for a considerable time. The precipitate thus obtained was boiled with lixivium of potash; it was then edulcorated, dried, made red-hot with wax in a covered porcelain crucible, was completely taken up by a magnet, and, being weighed, amounted to 80 grains.

C. The lixivium of potash was examined by muriate of ammonia, but no alumina was obtained.

D. To the filtrated liquor from which the iron had been precipitated by ammonia, muriate of barytes was added, until it ceased to produce any precipitate; this was then digested with some very dilute muriatic acid, was collected, washed, and, after exposure to a low red heat for a few minutes in a crucible of platina, weighed 155 grains. If therefore the quantity of sulphur, converted into sulphuric acid by the preceding operations, and precipitated by barytes, be calculated according to the accurate experiments of Mr. Chenevix, these 155 grains of sulphate of barytes will denote, nearly, 22.50 of sulphur; so that, with the addition of the 14 grains previously obtained in substance, the total quantity will amount to 36.50.

E. Moreover, from what has been stated it appears, that the iron which was obtained in the form of black oxide, weighed 80 grains: and, by adding these 80 grains to the 36.50 of sulphur, an increase of weight is found = 16.50. This was evidently owing to the oxidizement of the iron, which, in the magnetical pyrites, exists quite, or very nearly, in the metallic state, but, by the operations of the analysis, had received this addition. The real quantity of iron must, on this account, be estimated at 63.50.

100 grains, therefore, of the magnetical pyrites, yielded,

$$\begin{array}{llll} \text{Sulphur} & \left\{\begin{array}{ll} \text{A.} & 14. \\ \text{D.} & 22.50 \end{array}\right\} & 36.50 \text{ grains.} \\ \text{Iron} & \quad \text{E.} \quad = & 63.50 \\ \hline & & 100. \end{array}$$

The other varieties of pyrites were analyzed precisely in the same way.

1419. 100 parts of *crystallized protosulphate of iron* were analyzed as follows, in the laboratory of the Royal Institution. (*a*) The salt was reduced to powder, and dissolved in a small quantity of nitric acid; the solution was diluted, supersaturated by ammonia, and filtered. In this way the iron was separated in the state of peroxide, amounting to 28.5 grains, equivalent to 25.5 of protoxide of iron. (*b*) The filtered solution, now perfectly free from iron, but containing excess of ammonia, was neutralized by nitric acid, and nitrate of baryta was added till it ceased to form a precipitate. The sulphate of baryta thrown down was dried at a red heat and weighed 85 grains, indicating 28.7 of sulphuric acid: hence it appears that 100 grains of crystallized protosulphate of iron contain

25.5	protoxide of iron
28.7	sulphuric acid
54.2	

The loss, amounting to 45.8, is to be attributed to water of crystallization, for 100 grains of the crystals heated to dull redness for a quarter of an hour lose about 45 *per cent.*; hence the salt consists of

54.2	dry sulphate of iron
45.8	water of crystallization
100.	

The data upon which the composition of oxides of *iron* is *founded*, are given in paragraph 724.

1420. The analysis of *phosphate of iron* may be performed as that of phosphate of copper, which is given in Section 855.

1421. The analysis of the different kinds of iron produced by the manufacturer is attended with many difficulties, and has hitherto only been partially performed: on this subject some useful and interesting details will be found in Mr. Daniel's paper "On the mechanical structure of iron, *&c.*"—*Quarterly Journal of Science and Arts*, ii. 278.

1422. *Wootz* or *Indian steel* was examined in the laboratory of the Royal Institution by Mr. Faraday, as follows, with a view to detect its components, exclusive of carbon and iron.

A piece of wootz, weighing 164.3 grains, was placed in a flask, and acted on by nitro-muriatic acid and heat. It gradually dissolved, and dark-coloured flakes, separated from it, which were unalterable in the acid, though boiled with it. When all action had ceased, the solution was poured off from the sediment (*a*) which was repeatedly washed with distilled water; the solution was then examined carefully, but I could find nothing in it but iron. Whilst washing the sediment (*a*) it separated into two parts; a black powder (*b*) sank to the bottom of the water poured upon it whilst a reddish brown substance (*c*) in flocculi remained suspended; these were parted from each other.

The black powder (*b*) was fused with potash in a silver capsule, and then dissolved in water; it deposited a brown powder (*d*), and a clear alcaline solution was obtained. This was saturated with muriatic acid, and evaporated to dryness, and then being re-dissolved with a little excess of muriatic acid, a very small quantity of white flocculi were left untouched, which were insoluble in acids, and had the characters of *silex*. The solution acted on by subcarbonate of potash give an abundant precipitate. This was washed, and when heated with a little solution of potash, dissolved in it like *alumine*. Sulphuric acid was then added, and a solution of alum was obtained, a small quantity of silex precipitating.

The brown powder (*d*) deposited by the alcaline solution, was treated with nitric acid; a little heat being applied, nearly the whole was dissolved immediately, leaving a little of a black substance. The filtered solution gave a precipitate with muriate of soda, but when ammonia was added to it, the precipitate was re-dissolved, and a small quantity of iron was thrown down. The solution contained, therefore, *silver*, from the capsule in which the fusion had been made, and *iron* derived from the wootz. The black substance left by the nitric acid, was nearly all dissolved, by nitro-muriatic acid, iron being taken into solution, and a little of the substance (*b*) remaining.

The redish brown substance (*c*) was not affected by nitric acid, but, on adding solution of pure potash to it, a clear deep brown solution was obtained, and a blackish brown sediment (*e*) remained. When the alcali of the solution was neutralized by muriatic acid, flocculi, were precipitated, and the solution became colourless. These flocculi collected together and dried, proved to be combustible, and appeared to be merely modified tannin. The brown sediment (*e*) being then examined by muriatic acid, gave oxide of iron and a little *silex*.—*Quarterly Journal of Science and Arts*, vii. 288.

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SECTION X. *Of the Compounds of Zinc.*

1423. THE mode of ascertaining the composition of the oxide of zinc has been explained above, (767); it is only necessary to guard against the impurities of common zinc, which are chiefly iron, lead, and copper; the former is taken up by dilute sulphuric acid, and the two latter metals resist its action, and remain in the form of a black powder. Add to the sulphuric solution excess of ammonia, and apply a gentle heat; the oxide of iron will fall, and upon the addition of carbonate of potassa to the ammoniacal solution and boiling it, the pure oxide of zinc will be thrown down.

1424. The *oxide of zinc* of the *Pharmacopœia* is sometimes discoloured by a little iron; adulterated with chalk, or plaster of Paris; or contaminated by lead and arsenic. The presence of iron is shown by its solution in dilute nitric acid, neutralized by ammonia, becoming black with tincture of galls; chalk occasions an effervescence on adding the acid; gypsum is dissolved by boiling water, and detected by oxalate of ammonia and muriate of baryta. White arsenic is found by digesting in acetic acid, and adding solution of sulphuretted hydrogen, which occasions a yellow precipitate, in which arsenic is recognised by its smell when ignited on charcoal; and lead is shown by a black precipitate on adding sulphuretted hydrogen to the acetic solution.

1425. *Analysis of Chloride of Zinc.*—100 grains of chloride of zinc, obtained by heating the muriate in a glass tube to redness, and weighed while hot, to prevent error from deliquescence, were dissolved in water, and left 4 grains of oxide of zinc; accordingly 104 grains of the same chloride were dissolved, filtered, and decomposed by nitrate of silver, and the precipitate, washed, collected, and dryed at a red heat, weighed 203 grains, equal to 50.4 of chlorine. The solution from which the chloride was precipitated contained nitrate of zinc, with a little nitrate of silver; muriate of ammonia was added to throw down the silver, in the state of chloride, which was separated upon a filter, and the clear liquor, evaporated to dryness, and ignited, afforded 62 grains of oxide of zinc, equivalent to 49.5 grains of metal; hence 100 grains of chloride of zinc gave

50.5	chlorine
49.5	zinc
100.	

1426. *Analysis of Sulphuret of Zinc.*—A specimen of yellow blende was analyzed as follows by Dr. Thomson.—*Annals of Philosophy*, iv. 94.

a. 50 grains, in fine powder, were digested for two days in dilute nitric acid; the whole was then thrown upon a filter, and the undissolved residue, washed and dried at 110°, weighed 26 grains.

b. These 26 grains were put upon a watch-glass and heated by a lamp; they burned like sulphur, and left a residue of 22.4 grains; the 3.6 grains of loss were considered as sulphur.

c. The 22.4 grains residue, which had now assumed the appearance of the original blende, were again digested for two days with dilute nitric acid: the second day, as all action was over, and the whole nearly dissolved, the flask was exposed for some hours to a heat of 130°; the whole was then thrown upon a filter, and the undissolved portion, washed and dried, weighed 0.54 grains.

d. This small residue was burned as before, by which it lost sulphur amounting to 0.16 grains, and 0.38 grains of residue remained.

e. This 0.38 grains had the appearance of small particles of quartz, and weighed 0.38 grains.

f. The two portions of acid liquid, which had been digested on the ore, and which contained the greatest part of it in solution, were mixed together, and almost but not quite, saturated with carbonate of soda. A considerable excess of caustic ammonia was then poured in. By this alcali the oxide of iron was thrown down in yellowish red flocks, while the whole of the zinc was held in solution. The oxide of iron being separated by the filter, washed, dried, and heated to redness, weighed 8.5 grains. Now this is equivalent to 5.98 grains of metallic iron.

g. The residual liquor was now boiled in a glass retort down to half its bulk, in order to drive off the ammonia, and precipitate the oxide of zinc. About one half of that oxide precipitates after a few minutes' boiling, but it requires considerable concentration before the other half falls down. From this circumstance it is not improbable that ammonia and oxide of zinc unite in two proportions.

The oxide of zinc thus obtained being washed, dried, and heated to redness, weighed 36.4 grains. This is equivalent to 29.32 grains of metallic zinc. It may be proper to mention that the oxide of zinc thus obtained, was not quite white, but had a slight tinge of green. I conceived that this might be owing to the presence of copper, but if this metal was actually present, it was in too minute a quantity to be detected by the usual tests.

h. The liquid thus freed from iron and zinc, was mixed with nitric acid, till it acquired a perceptibly sour taste. This was done to prevent any inaccuracy from the presence of ammonia, if any should still remain in the liquid. A solution of muriate of barytes was then mixed with it. The sulphate of barytes which precipitated, being washed, dried, and heated to redness, weighed 77.616 grains. Now 77.616 grains of sulphate of barytes contain 26.4 grains of sulphuric acid, or 10.56 grains of sulphur. From the preceding analysis it appears that blende is composed of the following ingredients :

Zinc	29.32	58.64
Sulphur	14.32	28.64
Iron	5.98	11.96
Quartz	0.38	0.76
	50.00	100.00

1427. I adopted the following process in the analysis of the crystallized *black blende* of Derbyshire :

a. 100 grains carefully separated from its siliceous matrix, were reduced to a fine powder, and dried at 600°. The loss of weight indicates water.

b. Upon the dried and powdered ore put into a Florence flask, I poured 2 ounces of nitro-muriatic acid, consisting of two of nitric and one of muriatic acid, in small successive portions, taking care to moderate the effervescence, and when this had subsided, a sulphureous magma floated upon the acid : the flask was placed in a sand heat, and with one additional ounce of nitro-muriatic acid, was digested until nearly the whole of the sulphur had disappeared, being converted into sulphuric acid. The whole contents of the flask were then poured into a conical glass, to allow a portion of undissolved matter to subside, which was separated by decantation, and proved to be silica, mixed with a little pure sulphur, the quantity of which was determined by burning it off, and ascertaining the loss of weight.

c. The decanted acid liquor was now evaporated considerably, so as to dissipate a portion of its excess of acid, and the residue divided into two equal portions, A and B. To A, considerably diluted with water, I added nitrate of baryta, and the precipitate being collected, washed, and dried at a red heat, was pure sulphate of baryta, and was used as the equivalent of the sulphur in the ore.

d. Carbonate of soda was added to the portion B, which threw down every thing, and the precipitate composed of the carbonate of zinc and peroxide of iron was digested in liquid ammonia, which took up the carbonate of zinc, leaving the oxide of iron undissolved.

e. The alcaline solution of zinc was decomposed by the addition of muriatic acid in slight excess, and to the acid muriate of potassa a little carbonate of soda was added to ensure the entire separation of the zinc ;

the zinc precipitate was now washed, dried, and ignited to reduce it to the state of pure oxide of zinc.

f. This ore contained neither copper nor arsenic, which are sometimes present in it.

1428. *Analysis of Calamine* (782).—Mr. SMITHSON (*Phil. Trans.*, 1803.) was the first to show that there are two distinct varieties of calamine; the one a true carbonate of zinc, and the other a compound of oxide of zinc and silica.

A specimen of crystallized calamine from Derbyshire afforded in the 100 parts

Silica	0.8
Oxide of iron	1.5
Oxide of zinc	65.0
Carbonic acid	32.7
	100.

The above ore was digested in dilute muriatic acid, in which it slowly dissolved with effervescence, with the exception of 0.8 grains of silica. The solution was evaporated to dryness, and the dry residue redissolved perfectly in water, leaving no further portion of silica. To this aqueous solution caustic ammonia was added in excess, so as to re-dissolve the oxide of zinc at first thrown down, and the whole thrown upon a filter, on which there remained 1.5 grains of oxide of iron. The ammoniacal solution was supersaturated by muriatic acid, and carbonate of ammonia was added to throw down the whole of the zinc, which precipitate, being dried and ignited, weighed 65 grains. The filtered solution was evaporated to dryness, and the residue being heated in a platinum capsule, entirely evaporated, and was merely muriate of ammonia. The loss therefore of 32.7 parts in the hundred may be regarded as carbonic acid.

1429. A specimen of *electric calamine* in small acicular crystals afforded, by digestion in nitric acid, a residue of 38.5 *per cent.* silica, which being separated by a filter, the filtrated liquor evaporated to dryness, and the dry mass, ignited for a quarter of an hour, gave 60 *per cent.* of oxide of zinc. The loss may be regarded as water, for the calamine lost upon ignition 2 *per cent.* in weight.

1430. *Assay of Zinc Ores.*—To ascertain the value of a sample of zinc ore, two methods may be resorted to. 1. Pick out the impurities and weigh off 1000 grains of the picked ore; give it a dull red heat in a muffle, taking care not to fuse it: mix the roasted ore with half its weight of lamp-black, put it into a small coated glass retort with its neck drawn to a very small aperture, and give it a red heat for one hour; cool it gradually, and the zinc will be found in drops in its neck. 2. Prepare and roast the ore as before, and stratify it in a crucible with its weight of clippings of sheet copper; lute a cover on the crucible, and give it a dull white heat for an hour. When cold, throw the contents into water, by which the brass may be separated from the other matter, and its increase of weight compared with the original copper gives the addition of zinc. In this process, however, a portion of zinc is always lost.

SECTION XI. *Of the Compounds of Tin.*

1431. THE *native oxide of Tin* (792) or *tin-stone*, in consequence of its mechanical aggregation, is almost insoluble in the acids, but it is rendered soluble by fusion with potassa, as Klaproth first remarked. (*Analytical Essays*, i. 522.) The following is the process given by that excellent analyst, and from the relative proportion of the tin to the oxygen, it appears that the metal exists in this ore in the state of peroxide.

a. 100 grains of tin-stone, from Cornwall, previously ground to a subtile powder, were mixed in a silver vessel with a lixivium containing 600 grains of caustic potash; this mixture was evaporated to dryness, and ignited for half an hour; when the mass thus obtained had been softened with boiling water, it left on the filter 11 grains of an undissolved residue.

b. These 11 grains again ignited with six times their weight of caustic potash, and dissolved in boiling water, left now only 1.25 grains of a fine yellowish-grey powder behind.

c. The alcaline solution (*a* and *b*) was saturated with muriatic acid, and oxide of tin was thrown down; this precipitate re-dissolved by an additional quantity of muriatic acid was precipitated afresh by means of carbonate of soda; when lixiviated and dried in a gentle heat, it acquired the form of bright yellowish transparent lumps.

d. This precipitate being finely powdered, entirely dissolved in muriatic acid, assisted by a gentle heat. Into the colourless solution, previously diluted with from two to three parts of water I put a stick of zinc, and the tin thus reduced gathered around it in delicate dendritic laminæ of a metallic lustre; these, when collected, washed, dried, and fused under a cover of tallow, in a capsule placed upon charcoal, yielded a button of pure tin weighing 77 grains.

e. The above-mentioned residue of 1.25 grains, left by the treatment with caustic potash (*b*), afforded with muriatic acid a yellowish solution, from which, by means of a little piece of zinc introduced into it, 0.5 grain of tin was still deposited; Prussian alcali added to the remainder of the solution, produced a small portion of a light blue precipitate, of which, after subtracting the oxide of tin now combined with it, hardly ¼ of a grain remained, to be put to the account of the iron contained in the tin-stone, here examined.

In these experiments (excepting only a slight indication of *silex* amounting to about ¾ of a grain), no trace has appeared, either of tungstic oxide, which some mineralogists have supposed to be one of the constituent parts of tin-stone, nor of any other fixed substance. Therefore, what is deficient in the sum, to make up the original weight of the fossil analyzed, must be ascribed to the loss of oxygen; and thus the constituent parts of this ore are to each other in the following proportion:

Tin	77.50
Iron	0.25
Silex	0.75
Oxygen	21.50
	100.

1432. Dr. Davy (*Phil. Trans.*, 1812.) in his analyses of the *Chlorides of Tin* (794, 795.) separated the metal by the immersion of a plate of zinc; from 67.5 grains of *chloride of tin* he thus procured 42. of metallic tin, whence inferring the proportion of chlorine from the loss of weight, he concludes that this chloride is composed of

62.22	tin
37.78	chlorine

In consequence of the volatility of the *perchloride of tin*, it is very difficult to weigh it with perfect accuracy; it was therefore poured into a bottle half-full of water, the weight of which was previously ascertained, and its quantity inferred by the increase of weight. The water was rendered slightly acid by muriatic acid, and 81.75 grains of the perchloride gave by the immersion of zinc 34 grains of tin: hence 100 of the perchloride may be regarded as consisting of

42.1	tin
57.9	chlorine

The quantity of chlorine in the chloride of tin cannot be ascertained by nitrate of silver, in consequence of the reduction of a portion of the silver; but having thrown down the zinc, the dissolved chloride of zinc may be decomposed by nitrate of silver, and thus the quantity of chlorine originally united to the tin may be ascertained.

1433. The following is Klaproth's analysis of the *Cupreous Sulphuret of Tin*, called *tin pyrites*, or *bell-metal ore*, from *St. Agnes* in Cornwall.

a. 120 grains of finely triturated tin-pyrites were treated with an aqua regia, composed of one ounce of muriatic and ½ ounce of nitric acid. Within twenty-four hours the greatest part of the metallic portion was dissolved without heat, while the sulphur floated on the surface; after the mixture had been digested for some time in a sand-heat, I diluted it with water, and filtered; it left 43 grains of sulphur, still mixed with metallic particles; when the sulphur had been gently burnt off on a test, there still remained 13 grains; of which eight were dissolved by nitro-muriatic acid: the remaining part was then ignited with a little wax; upon which the magnet attracted one grain of it. What remained was part of the siliceous matrix, and weighed three grains.

b. The solution of the metallic portion (*a*) was combined with carbonate of potash; and the dirty-green precipitate thus obtained was re-dissolved in muriatic acid diluted with three parts of water; into this fluid a cylinder of pure metallic tin weighing 217 grains was immersed: the result was that the portion of copper contained in the solution deposited itself on the cylinder of tin, at the same time that the fluid began to lose its green colour, from the bottom upwards, until, after the complete precipitation of the copper in the reguline state, it became quite colourless.

c. The copper thus obtained weighed 44 grains; by digestion in nitric acid it dissolved, and left one grain of tin behind in the character of a white oxide; thus the portion of pure copper consisted of 43 grains.

d. The cylinder of tin employed to precipitate the copper now weighed 128 grains, so that 89 grains of it had entered into the muriatic solution; from this, by means of a cylinder of zinc, I re-produced the whole of its dissolved tin, which was loosely deposited on the zinc in a tender dendritical form. Upon being assured that all the tin had been precipitated, I collected it carefully, lixiviated it cleanly, and suffered it to dry; it weighed 130 grains. I made it to melt into grains, having previously mixed it with tallow, under a cover of charcoal-dust, in a small crucible, which done, I separated the powder of the coal by elutriation; among the washed grains of tin, I observed some black particles of iron, which were attracted by the magnet, and weighed one grain; deducting this, there remain 129 grains for the weight of the tin; by subtracting again from these last, those 89 grains, which proceeded from the cylinder of tin employed for the precipitation of the copper (*b*), there remained 40 grains for the portion of tin contained in the tin pyrites examined. Hence, including that one grain of tin which had been separated from the solution of the copper (*c*), the portion of pure tin contained in this ore amounts to 41 grains.

The *educts* or substances extracted in this process from tin pyrites were consequently

Sulphur	30 grains
Tin	41
Copper	43
Iron	2
Vein-stone or gangue	3
	119

Which makes, in a hundred parts,

Sulphur	25
Tin	34
Copper	36
Iron	2
	97

1434. *Assay of Tin Ores.*—If the ore contain arsenic, it should be powdered, mixed with a little charcoal, and roasted till vapours no longer rise. The residue mixed with a little pitch and sawdust, is to be put into a covered crucible, and exposed in a wind-furnace to a bright red heat for half an hour; when cool, break the crucible, and the button of metallic tin will be found at the bottom, which may be cleaned by gentle hammering and a wire brush, and weighed. The richest ores afford about 70 *per cent.* of metal.

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Section XII. *Of the Compounds of Cadmium.*

1435. We are as yet too little acquainted with the states of combination in which cadmium exists in its ores, and with the properties of the metal itself, to lay down precise rules for their analysis.

Mr. Stromeyer directs the digestion of the mixed oxide of zinc and cadmium in sulphuric acid, and passing through the acidulous solution a current of sulphuretted hydrogen gas: re-dissolve the precipitate in muriatic acid, evaporate to dryness, dissolve the residue in water, and precipitate by carbonate of ammonia, of which add excess to re-dissolve oxide of zinc, and of copper should any be present; carbonate of cadmium remains.

According to Stromeyer, 100 parts of cadmium, when converted into oxide, absorb 14.35 of oxygen, and

14.35 : 100 :: 8 : 55.75

So that, upon this datum, the number 55.8 may be assumed as the equivalent of cadmium; a number widely different from that given above, 819, and 63.8 will be the representative of oxide of cadmium.

1436. The following are Stromeyer's analyses of the nitrate, sulphate, and carbonate of cadmium.—GILBERT'S *Annalen*, lx.:

Nitrate . .	100	nitric acid
	117.58	oxide of cadmium
Sulphate .	100	sulphuric acid
	161.1	oxide of cadmium
Carbonate	100	carbonic acid
	292.8	oxide of cadmium

Now if we deduce the number for the oxide from the mean of these experiments, it will be about 64.1, which gives 56 as the equivalent of the metal.

Upon the same authority, the chloride, iodide, and sulphuret of cadmium may each be regarded as composed of one proportional of each of their components.

1437. The *Nitrate of Cadmium* is a white prismatic deliquescent salt composed of

1	proportional oxide	64
1	——— acid	54
4	——— water, 9 × 4 =	36
		154

1438. *Sulphate of Cadmium* forms large prismatic crystals, much resembling those of sulphate of zinc; very soluble and efflorescent, undergoing no change at a low red heat, but losing acid when heated to a bright red. It consists of

1	proportional oxide	64
1	——— acid.	40
4	——— water, 9 × 4 = . .	36
		140

1439. *Carbonate of Cadmium* is a white insoluble powder easily decomposed at a red heat. It consists of

1	proportional oxide	64
1	——— acid	22
		86

SECTION XIII. *Of the Compounds of Copper.*

1440. THE method of determining the composition of the *Oxides of Copper* is described in paragraph 827.

1441. *Chloride of Copper* (829) was thus analyzed by Dr. Davy.—*Phil. Trans.*, 1812. p. 172:

a. 80 grains were dissolved in nitro-muriatic acid, and a plate of iron was immersed, upon which copper was precipitated, weighing, when well washed and perfectly dry, 51.2 grains.

b. The same quantity of the chloride, dissolved in nitric acid, and precipitated by nitrate of silver, afforded 117.5 grains of dry chloride of silver.

c. Since chloride of silver contains 24.5 *per cent.* of chlorine, 80 grains of chloride of copper must contain 51.2 grains of copper, (*a.*) and 28.8 of chlorine, and 100 will consist of 36 chlorine + 64 copper.

The *Perchloride of Copper* may be analyzed exactly in the same way.

1442. The *Native Black Sulphuret of Copper* (844), or *Vitreous Copper Ore*, should consist in theory of

80 copper
20 sulphur

100

In the following analysis of this ore by Klaproth (*Essays*, i. 542), there is a close approach to these numbers; he probably lost a little sulphur by acidification, which might have been estimated by nitrate of baryta.

a. Upon 200 grains of the ore, coarsely powdered, moderately strong nitric acid was affused, which attacked and dissolved them with frothing and extrication of red vapours. The solution was clear, and the sulphur alone in the ore was left behind, floating in the fluid, in grey loose flocculi, without any other residue, which indicated that no antimony was present. The sulphur collected on the filter was heated in a small crucible to inflammation, and it burned with its peculiar odour, without any trace of arsenic; yet leaving a slight portion of oxided iron and siliceous earth.

b. The solution, which had a pure blue colour, was treated first with muriate and then with sulphate of soda, but these produced no alteration, by which it appears that this ore contains neither silver nor lead.

a. 200 grains of the powdered ore were heated with muriatic acid; as this alone manifested no action, I added nitric acid by drops, which exerted a strong attack. When the solution of the ore had been accomplished, I separated the fluid from the sulphur floating on the surface, and digested this last with a fresh quantity of muriatic acid, dropping into it some nitric acid; after which I collected it upon the filter. This sulphur, washed and desiccated, weighed 38½ grains, out of which after its combustion 1½ grain of siliceous earth remained; so that the true amount of sulphur was 37 grains.

b. The solution exhibits a glass-green colour. I divided it into two parts. Into one half polished iron was immersed, upon which the copper precipitated. It weighed 78½ grains when washed, and desiccated.

c. In order to ascertain the proportion of iron contained in the ore, I combined the other half of the solution with caustic ammoniac added to excess. The iron remained behind, in the form of brown oxide, which, collected on the filter, desiccated and ignited, weighed three grains. But as the iron is contained in the mixture of the ore in the reguline metallic state, these 3 grains give 2¼ of metallic iron to be added in the computation.

Therefore one hundred parts of the Siberian vitreous copper ore consist of

Copper, *b*	78.50
Iron, *c*	2.25
Sulphur, *a*	18.50
Silex, *a*	0.75
	100.

The same method of analysis applies to the other sulphurets of copper or copper pyrites.

1443. The *Ferro-arsenical Sulphuret of Copper*, (844), was analyzed as follows by Mr. R. Phillips.—*Quarterly Journal of Science and Arts*, vii. 100.

a. Having ascertained that the constituents of this ore are copper, iron, arsenic, and sulphur, I boiled 100 grains of it reduced to powder in nitric acid, until the whole of the metallic matter appeared to be dissolved. 14 grains remained unacted upon by the acid; of these a large portion was evidently pure sulphur; by heat 9 grains were volatilized, and 5 remained, which were merely silica that had been mechanically mixed with the ore.

b. The nitric solution was decomposed by potash, and being heated with excess of it, peroxide of copper and iron were precipitated together. This mixed precipitate was washed until it ceased to be alcaline, and was then dissolved in nitric acid. To the solution ammonia in excess was added; by this, peroxide of iron was precipitated, and the peroxide of copper held in solution; the former being separated, washed, and ignited, weighed 13.3 grains, equivalent to 9.26 of iron.

c. The ammoniacal solution of copper was heated, and when the greater part of the ammonia was expelled, potash was added to the solution; and, by continuing the heat, peroxide of copper was precipitated, which being washed and ignited, weighed 56.6 grains, equivalent to 45.32 of copper.

d. The alcaline solution obtained in *c*, and the water employed to wash the mixed precipitate of oxide of copper and iron, were evaporated together, and then saturated with nitric acid. This solution contained the sulphur and arsenic converted into acids, and combined with potash. Nitrate of barytes being added, sulphate was precipitated, which, being washed and ignited, weighed 126 grains, equal, according to Dr. Wollaston's scale, to 17.14 of sulphur, which, added to 9, before obtained, = 26.14. After this an accident happened to the solution, which prevented the separation of the arsenic acid; therefore, *e.* 160 grains of the ore were again treated with nitric acid; with the silica 11 grains of sulphur were obtained, and the nitric solution was decomposed by excess of potash as before, in order to separate the oxide of copper and iron.

f. The alcaline solution being saturated with nitric acid, nitrate of barytes was added to it, as long as precipitation took place. The precipitated sulphate of barytes being washed and ignited, weighed 150 grains, = 20.4 sulphur, which added to 11, separated without acidifying, = 31.4; the mean quantity of this and the first experiment being 28.74.

g. To the solution from which the sulphuric acid had been separated by nitrate of barytes, nitrate of lead was added as long as arseniate of lead was thrown down; and this, when washed and ignited, weighed 53 grains.

According to Dr. Thomson, 21.25 of arseniate of lead contain 7.5 of arsenic acid, equivalent to 4.75 of arsenic; if then, 21.25 give 4.75; 53 of arseniate of lead will indicate 11.84 of arsenic. It appears from these experiments, that this ore consists of nearly

Silica	5.
Iron	9.26
Copper	45.32
Sulphur	28.74
Arsenic	11.84
	100.16

In performing this analysis, some circumstances occurred which I think worthy of notice. In a preliminary experiment, I endeavoured to separate the copper from the iron by means of ammonia, without previously separating the arsenic acid; this I found impracticable, for it appeared that the arseniate of iron, at first precipitated, was eventually dissolved by the ammonia. In some treatises on chemistry, the arseniate of barytes is described as an insoluble salt: this, as may be deduced from what I have stated, is not the case. I first tried it by pouring a solution of arseniate of potash into one of nitrate of barytes; no precipitation occurred, but, upon standing some days, very delicate feathery crystals of arseniate of barytes were formed, which exhibited the prismatic colours with a splendour equal to that of the noble opal. I have since attempted, but without success, to reproduce the salt having this appearance*.

1444. *Native Phosphate of Copper* was analyzed by Klaproth nearly as follows: The ore was digested in nitric acid, by which it was entirely dissolved, with the exception of a remnant of silica. The nitric solution was divided into two parts; the phosphoric acid was precipitated from one, in the state of phosphate of lead, by adding acetate of lead; and from the weight of the phosphate of lead, the quantity of phosphoric acid was calculated. The other half of the solution was acted upon by iron to throw down the copper. He concluded from these experiments that the ore contained

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* In paragraph 1031, it is stated, that when *neutral* arseniate of potassa is added to nitrate of baryta an insoluble arseniate of baryta is thrown down, but if the binarseniate of potassa (1028) be used, the appearances are as above-described by Mr. Phillips, unless the solutions be very concentrated, in which case arseniate of baryta is presently thrown down.

68.13	oxide of copper
30.95	phosphoric acid
99.08	

It does not however seem clear whether the native phosphate of copper is a subphosphate of the peroxide, or a neutral phosphate of the protoxide; that is, whether it consists of 80 peroxide + 28 phosphoric acid; or of 72 protoxide + 28 phosphoric acid, these compounds requiring further investigation.

1445. *Native Carbonates of Copper.*—These, as well as the artificial carbonates have been analyzed by Mr. R. Phillips (*Quarterly Journal of Science and Arts*, iv. 274), and the results are given above, (857, *&c.*) The following is the process which he employed:

200 grains of green carbonate of copper heated to redness in a platinum crucible, became perfectly black, and lost 55.6 grains.

I put some nitric acid into a small phial, the stopper of which had been perforated, and a glass tube passed through it, to suffer the escape of the carbonic acid gas; the weight of the phial and acid being taken, I gradually put into it 200 grains of green carbonate of copper in small fragments. When the solution was complete, I found that 37 grains of carbonic acid had been evolved. If then from 200 we subtract 55.6, the loss by heat, we have 144.4 as the quantity of peroxide of copper; and if from 55.6 we take 37, the carbonic acid, there remain 18.6 as the proportion of water dissipated by heat. 100 parts of green carbonate of copper consist therefore of

Peroxide of Copper	72.2
Carbonic acid	18.5
Water	9.3
	100.0

On examining the solution I found it to be pure nitrate of copper.

1446. The following comparative results will show how near in this instance experiment agrees with theory, if we regard the green carbonate of copper, or *malachite*, as consisting of 1 proportional of peroxide of copper, 1 of carbonic acid, and 1 of water; or as an hydrated subcarbonate.

	Vauquelin.	Phillips.	Theory.
Peroxide of copper . . .	70.10	72.2	72.01
Carbonic acid	21.25	18.5	19.82
Water	8.65	9.3	8.17
	100.00	100.0	100.00

1447. *Assay of Copper Ores.*—When the ores contain sulphur and arsenic, they are roasted till fumes no longer arise, or reduced to powder and deflagrated with nitre. The residue is mixed with black flux (1012), and exposed for one hour to a bright red heat in a wind-furnace, when a button of copper is formed at the bottom of the crucible, the purity of which may be judged of by its appearance and malleability.

The oxides and carbonates of copper are reduced by simple fusion with black flux, care being taken to raise the heat sufficiently.

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SECTION XIV. *Of the Combinations of Lead.*

1448. LEAD constitutes a component part of several complex ores, the analyses of which are described in the sections on antimony and silver.

1449. *Galena* or *Sulphuret of Lead* (885) may be analyzed by the action of dilute nitric acid, which dissolves the lead and separates the sulphur: the lead may be precipitated by sulphate of soda; 100 grains of the sulphate of lead thus thrown down, after having been dried at a dull red heat, are equivalent to 69 of lead.

1450 Vauquelin analyzed a galena from Cologne, as follows. (*Journal des Mines*, No. 68.) It was heated with very dilute nitric acid; the undissolved residue, consisting of silica and sulphur, was heated to redness, by which the latter was dissipated, and pure silica remained. The nitric solution was decomposed by sulphate of soda, and the sulphate of lead collected, dried, and weighed, to estimate the proportion of metal. The remaining liquor being saturated by ammonia, gave a precipitate of oxide of iron; and lastly, carbonate of ammonia threw down carbonate of lime.

1451. A native *Sulphate of Lead* from Anglesea (889) was thus analyzed by Klaproth: 100 grains moderately heated lost 2 of water; the remainder was fused in a platinum crucible with four parts of carbonate of potassa, which gave a yellow hard mass partly soluble in water; the insoluble residue when dry was 72 grains of oxide of lead; it was dissolved in nitric acid, and this solution gave, when decomposed by the immersion of a rod of zinc, 66.8 grains of metallic lead. The alcaline solution from the crucible was saturated with nitric acid, and acetate of baryta added as long as it occasioned a precipitate, which weighed when quite dry 73 grains, equal to 25 of sulphuric acid. Hence it appears that this ore contains

66.5 lead . . . . 5.5 oxygen	= 72 oxide of lead
	25 sulphuric acid
	97
Loss, consisting of 1 gr. of oxide of iron, and 2 of water	3
	100.

1452. *Native Phosphate of Lead* (896) was also examined by Klaproth; it is a distinctive character of this compound, that when fused into a globule before the blow-pipe, it assumes, as it cools, a dodecaëdral form. 100 grains of green prismatic phosphate of lead dissolved entirely in nitric acid. Nitrate of silver gave a precipitate of 11 grains of chloride = 2.7 of chlorine. Sulphuric acid added to the warm solution gave 106 of sulphate of lead = 78.4 of oxide of lead: the liquor was then freed from excess of sulphuric acid by nitrate of baryta, and after having been nearly saturated by ammonia, acetate of lead was added; the phosphate of lead thus precipitated weighed 82 grains = 18.37 of phosphoric acid (more correctly 16.5). In the residuary solution was found a trace of iron.

1453. *Native Carbonate of Lead* (898) may be thus analyzed. Reduce the ore to powder and introduce 100 grains into a sufficient quantity of nitric acid diluted with about two parts of water; an effervescence ensues, and the carbonic acid may be estimated by loss of weight; it amounted to 16 grains. Filter the nitric solution, and if there be any insoluble residue, it is probably silica; to the filtered liquor add sulphate of soda, which throws down sulphate of lead, whence the oxide may be deduced; or immerse a plate of zinc into the nitric solution, which throws down metallic lead: in Klaproth's analysis he thus obtained 77 of metal equivalent to 82.5 oxide; whence it appears that the native carbonate contains

16.	carbonic acid
82.5	oxide of lead
98.5	

These numbers almost exactly agree with the theoretical composition of the carbonate of lead; the loss amounting to 1.5 may probably be considered as 0.5 carbonic acid and 1. water.

1454. The *Murio-Carbonate of Lead*, or *Native Muriate of Lead* (877), as it is generally called, was analyzed as follows, by Mr. Chenevix. (NICHOLSON'S *Journal*, 4to. iv.) 100 grains, dissolved in nitric acid, lost 6 of carbonic acid; the nitric solution was neutralized by ammonia, and the absence of arsenic, phosphoric, and sulphuric acids proved by tests. Nitrate of silver was then added, which formed a copious precipitate, weighing when dry 48 grains, equivalent, according to Mr. Chenevix, to 8 of muriatic acid; he concludes that the 6 grains of carbonic acid saturated 34 of oxide of lead, and that 8 of muriatic acid saturated 51 of oxide of lead; and therefore, that the ore consists of 59 muriate of lead and 40 carbonate of lead.

Klaproth's analysis agrees almost exactly with that of Mr. Chenevix, and they give the following view of the composition of this ore, but there is probably some considerable error in the estimate of the muriatic acid, and a new analysis is highly desirable.

Oxide of lead	85.5
Carbonic acid	6.
Muriatic acid	8.5
	100.0

1455. In the assay of lead ores by fire, a considerable loss is often sustained by the volatilization of the oxide of lead, and by its action upon the crucible, so that the operation is best performed by humid analysis; the ore may be digested in dilute nitric acid, and to the solution, when filtered, sulphate of soda may be added, which will throw down sulphate of lead; the latter, when washed and dried at a red heat contains about 68 *per cent.* of the metal.

SECTION XV. *Of the Combinations of Antimony.*

1456. THERE are three proper ores of antimony, *Native Antimony* (905), *Native Oxide of Antimony* (912), and the *Native Sulphuret* (905).

1457. Native antimony from Andreasberg was examined as follows by Klaproth (*Essays*, ii. 136.) 100 grains in powder were heated with nitric acid, the mixture diluted with water and filtered; muriatic acid, added to the filtered liquor, gave a precipitate of chloride = 1 grain of metallic silver; and the residual liquor gave oxide of iron = .25 grain of metallic iron. The oxide of antimony upon the filter was perfectly soluble in muriatic acid; a piece of zinc, immersed in this muriatic solution, gave 98 grains of metallic antimony; hence the components are

Antimony	98.
Silver	1.
Iron	0.25
	99.25

1458. The *Native Oxide*, or *white ore of Antimony* from Pritzbram, in Bohemia, was also analyzed by Klaproth; he found it a perfectly pure oxide, but did not ascertain the relative proportions of its component parts. According to Vauquelin, it contains silica and a little oxide of iron.—HAUY, iv. 274.

1459. The following is the analysis of an iridescent sulphuret of antimony, in acicular crystals, from Hungary.

a. 100 grains digested in two parts of nitric acid and one of water afforded a portion of sulphur, which, having been carefully separated from the adhering oxide, burned entirely away. It weighed 17.5 grains.

b. The insoluble oxide collected and washed, was re-dissolved in muriatic acid, and zinc immersed into the solution, by which 74 grains of metallic antimony were thrown down.

c. The nitric solution being evaporated to one-fourth, let fall a portion of white powder, which, treated as *b*, gave 2 grains of antimony.

d. The solution *c* appearing now to be free from antimony, was diluted and divided into two equal portions, A and B. Muriate of baryta, added to A, gave a precipitate of sulphate of baryta, weighing 22.5 grains, = about 3 grains of sulphur. or 6 in 100.

e. The portion B tested by muriate of soda gave no indication of silver; supersaturated with ammonia, it let fall 1.5 grains of peroxide of iron, to about 1 grain of iron.

f. The results of this analysis, therefore, are

Sulphur	*a.* 20.5 grs. *d.* 6.	23.5 grs.
Antimony	*b.* 74. grs. *c.* 2.	76.0
Iron	*e.*	2.
		101.5

The small increase of weight I refer to zinc adhering to the antimony.

1460. The *red ore of Antimony*, from Braunsdorff in Saxony, was analyzed by Klaproth; he digested it in muriatic acid, and threw down the antimony by water and potassa; the precipitate, after a second solution and precipitation, was re-dissolved in muriatic acid, and decomposed by a piece of polished iron, which caused the separation of 67.5 grains of metallic antimony. The sulphur he estimates at 19.70 *per cent.*, and attributes the loss of weight to oxygen combined with the antimony; he therefore regards the ore as a sulphuretted oxide of antimony, containing

Antimony	67.50
Oxygen	10.80
Sulphur	19.70
	98.

1461. The following is Mr. Hatchett's instructive analysis of *Bournonite*, or the *triple sulphuret of Lead*, *Antimony*, and *Copper:*

A. 200 grains of the ore, reduced to a fine powder, were put into a glass matrass, and, two ounces of muriatic acid being added, the vessel was placed in a sand-bath. As this acid, even when heated, scarcely produced any effect, some nitric acid was gradually added, by drops, until a moderate effervescence began to appear.

The whole was then digested in a gentle heat, during one hour; and a green-coloured solution was formed whilst a quantity of sulphur floated on the surface, which was collected, and was again digested in another vessel, with half an ounce of muriatic acid.

The sulphur then appeared to be pure, and, being well washed and dried on bibulous paper, weighed 34 grains: it was afterwards burned in a porcelain cup, without leaving any other residuum than a slight dark stain.

B. The green solution, by cooling, had deposited a white saline sediment; but this disappeared upon the application of heat, and the addition of the muriatic acid in which the sulphur had been digested.

The solution was perfectly transparent, and of a yellowish green: it was made to boil, and in this state was added to three quarts of boiling distilled water, which immediately became like milk; this was poured on a very bibulous filter, so that the liquor passed through before it had time to cool; and the white precipitate thus collected, being well edulcorated with boiling water, and dried on a sand-bath, weighed 63 grains.

C. The washings were added to the filtrated liquor; and the whole was gradually evaporated at different times, between each of which it was suffered to cool, and remain undisturbed during several hours. A quantity of crystallized muriate of lead was thus obtained, until nearly the whole of the liquor was evaporated: to this last portion a few drops of sulphuric acid were added, and the evaporation was carried on to dryness; after which the residuum, being dissolved in boiling distilled water, left a small portion of sulphate of lead.

The crystallized muriate of lead was then dissolved in boiling water; and, being precipitated by sulphate of soda, was added to the former portion, was washed, dried on a sand-bath, and then weighed 120.20 grains.

D. The filtrated liquor was now of a pale bluish-green, which changed to deep blue, upon the addition of ammonia; some ochraceous flocculi were collected, and, when dry, were heated with wax in a porcelain crucible, by which they became completely attractable by the magnet, and weighed 2.40 grains.

E. The clear blue liquor was evaporated nearly to dryness; and, being boiled with strong lixivium of pure potash, until the whole was almost reduced to a dry mass, it was digested in boiling distilled water; and the black oxide of copper, being collected and washed on a filter, was completely dried, and weighed 32 grains.

200 grains of the ore, treated as here stated, afforded,

	Grains.
A. Sulphur	34.
B. Oxide of antimony . . .	63.
C. Sulphate of lead	120.20
D. Iron	2.40
E. Black oxide of copper	32.

But the metals composing this triple sulphuret are evidently in the metallic state; and white oxide of antimony precipitated from muriatic acid by water, is to metallic antimony as 130 to 100; therefore, the 63 grains of the oxide must be estimated at 48.46 grains of the metal.

Again, sulphate of lead is to metallic lead as 141 to 100; therefore, 120.20 grains of the former are = 85 24 grains of the latter. And, lastly, black oxide of copper contains 20 *per cent.* of oxygen; consequently, 32 grains of the black oxide are = 25.60 grains of metallic copper.

The proportions for 200 grains of the ore, will therefore be,

Sulphur	34.
Antimony	48.46
Lead	85.24
Iron	2.40
Copper	25.60
	195.70
Loss	4.30

◆

SECTION XVI. *Of the Combinations of Bismuth.*

1462. THE principal ores of bismuth are, *Native Bismuth*, the *Sulphuret*, the *plumbo-cupriferous Sulphuret*, and the *Native Oxide*. Klaproth's analysis of the bismuthic silver ore will be found in a following Section.

1463. The *Sulphuret of Bismuth* has been analyzed by Sage (*Mém. de l' Acad. des Scien.*, 1782, p. 307.) but the following more complicated analysis of one of the ores of this metal renders it unnecessary to advert to other details.

1464. The *needle ore* of Siberia, or *Sulphuret of Lead, Copper, and Bismuth*, was examined as follows :

a. 50 grains, separated as far as possible from its quartzose matrix, were digested in nitric acid diluted with its bulk of water ; when all action had ceased, a gentle heat was applied for a few hours, until no further action took place. The whole was then poured upon a filter, and the residue being washed and dried, weighed 8.8 grains ; it was burned, and there remained upon the capsule 2.3 grains of silica ; the burned portion, amounting to 6.5 grains, being considered as sulphur. There was also an inappreciable portion of sulphate of lead.

b. The filtered solution being evaporated, let fall crystals of nitrate of lead ; the evaporation was carried nearly to dryness, and the residue, put into 8 ounces of water, deposited a quantity of oxide of bismuth, which being collected, washed, and dried, weighed 20 grains. On evaporating the filtered liquor to half its bulk, there was a further deposit of 3 grains of oxide of bismuth. Now, 23 grains of oxide of bismuth may be computed as equal to 20.5 of the metal.

c. The evaporation was now carried nearly to dryness, a portion of excess of acid driven off, and the residue again diluted, by which a very slight turbidness was produced, but no appreciable portion of bismuthic oxide deposited. I therefore poured sulphate of soda into the solution, and the precipitate of sulphate of lead thus formed, weighed, when dry, 18.5 grains, equivalent to about 12.7 of lead.

d. The filtered liquor was now evaporated to dryness, and the residue dissolved in a small quantity of water ; carbonate of soda was added, and the blue precipitate being collected and washed, was digested in ammonia, in which it was totally soluble ; the ammonia being driven off, the residue was heated red-hot, and had the properties of pure peroxide of copper ; it weighed 8 grains, which is nearly equivalent to 6.5 of copper.

These were all the components of this triple sulphuret which I could separate, though, from its odour before the blow-pipe, I suspect the existence of a trace of arsenic in it : the following, therefore, are the results of the analysis :—

Sulphur (*a*)	6.5 grains.
Bismuth (*b*)	20.5
Lead (*c*)	12.7
Copper (*d*)	6.5
	46.2
Silica (*a*)	2.3
Loss	1.5
	50.0

From the small quantity of the needle ore in my possession, I could not repeat this analysis, nor could I employ separate portions for the separation of its several components.

Dr. John (*Chemische Untersuchungen*, p. 216.) whose analysis is, I believe, the only one previously published, gives the following as the composition of this ore of bismuth :

Bismuth	43.20	21.60
Lead	24.32	12.16
Copper	12.10	6.05
Sulphur	11.58	5.79
Nickel	1.58	0.79
Tellurium	1.32	0.66
Gold	0.79	0.39
	94.89	47.44
Loss	5.11	2.56
	100	50.00

It may be observed, that in both these analyses, but especially in the latter, the proportion of sulphur falls short of that required to constitute the respective sulphurets of lead, copper, and bismuth, and that the loss therefore may be most plausibly ascribed to sulphur.

1465. The *Native Oxide of Bismuth* consists, according to Lampadius, of

Oxide of bismuth	86.3
Oxide of Iron	5.2
Carbonic acid	4.1
Water	3.4

Heat would expel both the water and carbonic acid from this compound: the relative proportion of the latter might be learned by the loss of weight during effervescence. The ore might then be dissolved in the smallest possible quantity of nitric acid, and excess of ammonia would precipitate the peroxide of iron, but retain the bismuth in solution; the oxide of bismuth might then be obtained by evaporation to dryness, and exposure to heat sufficient to decompose the nitrate of ammonia.

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SECTION XVII. *Of the Combinations of Cobalt.*

1466. THE analyses of the chloride and of the sulphate of cobalt are given in Section XVII. of the preceding Chapter, (paragraphs 960 and 969.) from which the equivalent of the metal is deduced.

The principal difficulties that occur in examining the combinations of cobalt are, its separation from arsenic, from nickel, and from copper, which may be performed as follows.

a. 100 grains of an alloy of cobalt, arsenic, nickel, and copper, are digested in nitric acid till perfectly dissolved; the solution is then evaporated to dryness, and a fresh portion of nitric acid distilled off the dry salt, in order to ensure the complete acidification of the arsenic; the residue, consisting of arseniates of cobalt, copper, and nickel, may then be treated by nitrate of lead, which will remove the arsenic acid in the form of insoluble arseniate of lead; but a more convenient method of proceeding is perhaps as follows: boil the arseniates repeatedly in solution of potassa, until that alcali no longer takes up arsenic acid; the oxides of cobalt, nickel, and copper, will thus be obtained nearly, if not quite, free from arsenic acid.

b. To separate the oxides of copper, cobalt, and nickel, dissolve them (in the state of hydrates) in dilute nitric acid, and immerse a plate of iron, which will throw down metallic copper, and a mixed nitrate of iron, cobalt, and nickel, will be obtained.

c. To this mixed nitrate add potassa, wash the precipitate, and digest it in ammonia, which will take up the oxides of cobalt and nickel, leaving the peroxide of iron.

d. The ammoniated solution of cobalt and nickel may be treated as directed by Mr. R. Phillips, (*Phil. Magazine*, xvi. 313.) Evaporate it till the excess of ammonia is expelled (which is known by no change of colour being produced by it on turmeric paper), and then add solution of potassa, and dilute considerably; the oxide of nickel instantly falls, but that of cobalt remains some time in solution, and may be obtained by neutralizing the alcaline liquor.

1467. The following is Tassaert's analysis of the *Arsenical Cobalt*, or *white cobalt glance* of Tunneberg.

That the reader may better understand the process, it may be premised, that when reguline arsenic is boiled with a *little* nitric acid, it is dissolved and converted into white oxide, all of which is deposited by mere evaporation to a small bulk of liquid; but when *much* nitric acid is used, the arsenic is more or less acidified, becomes thereby much more soluble in water, and then acting as an acid, it readily dissolves cobalt, iron, *&c.*, forming arseniates of those metals, which are decomposable by the fixed alcalis. It may be also added, that oxide of cobalt is soluble in ammonia, but oxide of iron is not; and that the nitrate of iron deposits much of its iron by mere exposure to air, but the nitrate of cobalt remains clear.

A. To estimate the quantity of arsenic separately, M. Tassaert digested 100 parts of the cobalt ore with dilute nitric acid, and in some hours the whole was dissolved, but by cooling deposited a quantity of white crystalline grains. On evaporation, more of them were deposited, and when all had thus separated, they were collected and dried, and weighed 56 parts, all of which was sublimed by heat except 3 parts, probably a mixture of arsenic and cobalt. Hence the oxide of arsenic from this ore may be reckoned at about 53 parts, indicating 49 per cent. of metallic arsenic in the ore.

B. 300 parts of the ore were then digested with four times as much nitric acid, which made a rose-coloured solution. By partial evaporation, adding water, and heating, a rose-white precipitate (*a*) fell down, leaving a rose-coloured solution. This solution, boiled with an excess of potash, gave an oxide of cobalt, at first rose-coloured, then passing to green, and, when dried in a red heat, black. It weighed 85 parts.

C. The 85 parts of the last experiment were then examined for iron. When re-dissolved in nitro-muriatic acid, pure ammonia was added, which gave a black precipitate, which was all re-dissolved by an excess of the alcali except a small portion, which, again treated with nitro-muriatic acid and ammonia, was reduced to 4 parts, and appeared to be oxide of iron.

D. The rose-precipitate of experiment B, which proved to be a mixed arseniate of cobalt and iron, was decomposed by caustic potash in excess, and gave a precipitate weighing 100 parts when dried.

E. The 100 parts of the last experiment were re-dissolved in nitric acid, the solution evaporated partly, and then diluted with water; a precipitate of oxide of iron weighing 27 parts then separated, and a clear solution of cobalt was left.

F. The nitrate of cobalt of the last experiment was decomposed by ammonia, and the precipitate re-dissolved by an excess of the alcali, except 15 parts of insoluble oxide of iron: the solution was added to the ammoniated cobalt of experiment C.

G. The insoluble precipitates of oxide of iron of C, E, and F, were then mixed and examined: they still gave a blue glass with borax, and therefore contained a certain portion of cobalt. Acetic acid was found a good method of separating them: for this purpose they were re-dissolved in nitro-muriatic acid, precipitated by just sufficient ammonia, and the precipitate whilst still wet was put into acetic acid. This dissolved the whole at first, but on boiling and evaporating the solution nearly to dryness, most of the iron separated, and by re-dissolving in water and evaporating nearly to dryness successively four times, nearly all the oxide of iron was rendered insoluble, whilst the cobalt remained in the solution, and this acetited cobalt in proportion as it was freed from iron became more and more of a fine rose colour. This last was then supersaturated with ammonia, and the solution of ammoniated cobalt was added to the different portions of the same obtained in the former experiments. The whole was then boiled to expel the excess of ammonia, and by adding potash the whole of the pure oxide was precipitated, which when well washed and dried, weighed 133 parts. This oxide reduced in a crucible lined with charcoal, gave regulus of cobalt in its purest form, of the specific gravity of 8.538, and to all appearance totally free from arsenic and iron.

H. Lastly, to estimate the quantity of sulphur, 100 parts of the ore were separately boiled with 500 of nitric acid, and diluted with water, to separate all the oxide of arsenic that would be deposited spontaneously. All the sulphur being now converted into sulphuric acid by the action of the nitric acid, nitrate of barytes was added, and from the precipitated sulphate of barytes, the quantity of sulphuric acid, and of course, of sulphur, was estimated according to known proportions. —AIKIN's *Dictionary*, i. 307.

SECTION XVIII. *Of the Combinations of Uranium.*

1468. IN Section XVIII. of the preceding Chapter, the *Pechblende* of mineralogists is erroneously represented as a *Native Sulphuret of Uranium*; it is, however an oxide of uranium, combined with a little oxide of iron, sulphuret of lead, and silica; probably accidental ingredients, as shown by the following results of Klaproth's analysis of the *pitch ore of uranium*, from Joachimsthal:

Oxide of uranium	86.5
Oxide of iron	2.5
Sulphuret of lead	6.0
Silica	5.0
	100.

1469. The following is a general process for the analysis of uranitic ores.

a. Digest in dilute nitric acid, which separates sulphur and silica (if sufficiently dilute without the acidification of the former); burn off the sulphur, and the silica remains.

b. To the nitric solution add sulphate of soda, which separates lead in the state of sulphate.

c. To the remaining solution add liquid potassa in excess, and boil; filter, wash the precipitate, and digest it in pure ammonia which takes up the copper, and which may be obtained by immersing a plate of zinc in the ammoniacal solution slightly supersaturated with sulphuric acid.

d. Digest the portion of the precipitate *c*, insoluble in ammonia, in bi-carbonate of potassa, which, if used in sufficient quantity, takes up oxide of uranium, leaving oxide of iron.

1470. The *Micaceous Uranite*, from the Gunnis Lake mine in Cornwall was analyzed as follows, by Mr. Gregor (*Annales of Philosophy*, v. 281.):

a. 100 grains lost, by exposure to a low red heat, 15.4 grains of water.

b. 100 grains (not previously ignited), repeatedly boiled in excess of nitric acid, left a residue amounting only to 0.1 grain of silica and oxide of iron.

c. Excess of ammonia added to the nitric solution, threw down a yellow precipitate, which, digested in excess of ammonia, gave a blue solution, and left 74.9 grains of oxide of uranium, not quite pure.

d. The ammoniacal solutions were evaporated to dryness, and the residue again digested in ammonia left 0.2 grains of oxide of uranium. The ammoniacal solution again evaporated, and the residue dissolved in nitric acid, gave with potassa a precipitate, which dried and ignited, was 7.65 grains of oxide of copper.

e The 74.9 grains of oxide *c*, digested in dilute sulphuric acid, *left* a trace of lead. The sulphuric solution, precipitated by excess of ammonia, still showed traces of copper, and by a cylinder of zinc gave 0.5 grain of metallic copper = 0.62 of oxide; so that the 74.9 grains of process *c* were reduced to 74.28, to which add the 0.2 grain of process *d*, and it gives the whole amount of oxide of uranium = 74.48. The results of the above analysis are

Oxide of uranium, with a trace of lead	74.48
Oxide of copper, *d e* . .	8.20
Water	15.40
	98.08
Loss	1.92
	100.00

SECTION XIX. *Of the Combinations of Titanium.*

1476. KLAPROTH and Vauquelin have furnished analyses of the titanic ores, of which the following examples will suffice.

The *silico-calcareous titanite* from Bavaria was thus analyzed by Klaproth (*Essays*, i. 214.):

a. 100 grains in fine powder were ignited for an hour with 400 grains of caustic potassa, and the resulting mass digested in muriatic acid left 12 grains of silica.

b. Carbonate of potassa was added to the muriatic solution, and the precipitate thus obtained, being again digested in muriatic acid, left 23 grains of silica.

c. Caustic ammonia was then added to the preceding solution, and the precipitate dried and ignited gave 33 grains of oxide of titanium.

d. To the remaining fluid, whilst boiling, carbonate of potassa was added, and the precipitate having been duly ignited, gave 33 grains of lime.

The following then are the component parts of this mineral:

Silica, *a b*	35 grains
Oxide of titanium, *c*	33
Lime, *d*	33
	101

1472. The following is Vauquelin's analysis of the *Menachanite* of Bavaria (*Journal des Mines*, No. 19.):

a. 100 grains finely pulverized were fused for an hour and a half in a silver crucible, with 400 grains of potassa; the fused mass, digested in water, left 124 grains of red insoluble powder.

b. The 124 grains were boiled with potassa, and the solution, after saturation with muriatic acid, was treated with carbonate of potassa, which threw down 3 grains of oxide of titanium.

c. The residue of the 124 grains was digested with dilute muriatic acid, which left 46 grains of oxide of titanium.

d. The muriatic solution, saturated by ammonia, gave 50 grains of oxide of iron.

e. The alcaline solution *a*, which was of a green colour, was supersaturated by muriatic acid, and evaporated to dryness; the dry residue contained no silica, for it dissolved entirely in water; on the addition of carbonate of potassa, it yielded 2 grains of carbonate of manganese.

SECTION XX. *Of the Combinations of Cerium.*

1473. *Cerite* (997) was analyzed, with the following results, by Vauquelin (*Annales du Muséum*, v. 412.):

67	oxide of cerium
17	silica
2	oxide of iron
2	lime
12	water and carbonic acid
100	

The following directions for the analysis of this ore are given by Messrs. Aikin:

a. Having minutely pulverized the ore, weigh it, then ignite it and weigh it again; the difference may be set down as the amount of water.

b. Digest the calcined ore in repeated portions of nitro-muriatic acid, and when nothing further is taken up, fuse the residue with caustic potash; then dissolve out the mass by muriatic acid, evaporate to dryness, and digest again in very dilute muriatic acid; the insoluble residue is silex.

c. Add together the muriatic and nitro-muriatic solutions, and decompose the whole at a boiling heat by saturated carbonate of potash; re-dissolve the whole in as little muriatic acid as possible, heat the solution to drive off the last remains of carbonic acid, and add perfectly caustic ammonia till there is an evident excess; separate the precipitate, and add to the clear liquor as much muriatic acid as will saturate it, and then throw down from it the lime in the state of carbonate, by means of a mild alcali.

d. The ammoniacal precipitate, consisting of the oxides of cerium and iron, is to be dissolved in muriatic acid, and liquid hydrosulphuret of potash is to be dropped in till the precipitate, which at first will be greenish, becomes white; the clear liquor being separated and treated with carbonate of potash, affords a white precipitate, which is carbonate of cerium.

e. The greenish precipitate is to be dissolved in as little muriatic acid as possible, and the solution being neutralized by an alcali to the point of precipitation, sulphate of soda is to be added, which will throw down a sulphate of cerium; the residual fluid being then decomposed by ammonia, deposits oxide of iron.

f. The sulphate of cerium *e* is now to be boiled with thrice its weight of carbonated soda, by which it will be converted into carbonate, which is to be dissolved in dilute muriatic acid, and again precipitated by carbonate of potash or of soda.

g. The carbonates of cerium (*d* and *f*) are now to be calcined, by which the pure brown oxide of cerium will be obtained.—*Addenda to the Dictionary*, iii. 509.

1474. *Allanite*, (997) analyzed by Dr. Thomson (*Edinburgh Phil. Trans*., vi. 385.) was found to contain the following substances:

Oxide of cerium	33.9
Oxide of iron	25.4
Silica	35.4
Lime	9.2
Alumina	4.1
Water	4.0
	112.0

◆

SECTION XXI. *Of the Combinations of Tellurium.*

1475. THE following is an outline of the analysis of several compounds of tellurium given by Klaproth, in his *Chemical Examination of the Auriferous Ores of Transylvania*, ESSAYS ii. 1.

1476. *Native Tellurium*, from Fatzebay in Transylvania, contains, according to that celebrated analyst,

92.55	tellurium
7.20	iron
0.25	gold
100.	

The following method was pursued in the decomposition of this ore:

a. It was separated as much as possible from its stony matrix and pulverized, was digested in six parts of warm muriatic acid, to which were added, cautiously and at intervals, three parts of nitric acid; the compound acid acted violently on the ore, and took up the whole of it except the quartzose matrix.

b. The acid solution being diluted with as much water as it would bear without decomposition, was combined with caustic potassa, upon which a copious precipitate fell down; more alcali was then added, till the whole of the precipitate that was resoluble in this menstruum was taken up. There remained behind a dark-brown residue, consisting of the oxides of gold and iron.

c The residue of *b* was then dissolved in nitro-muriatic acid, to which was afterwards added, drop by drop, nitrate of mercury, prepared in the cold, as long as the precipitate thus formed appeared of a brown colour; this precipitate, consisting of gold and muriate of mercury, was then pretty strongly ignited in a crucible with borax, by which the mercury was driven off, and a button of pure gold remained.

d. To the nitro-muriatic solution *c*, was now added caustic alcali, by which the oxide of iron was thrown down.

e. The alcaline solution *b* was accurately saturated with muriatic acid, and then heated, by which a white heavy powder was obtained; which, after being washed in a mixture of equal parts of alcohol and water, and then gently dried, was pure oxide of tellurium.

1477. The *grey ore of Tellurium*, or *Graphic Gold*, of Offenbanya, contains

60	tellurium
30	gold
10	silver.

This ore was treated in the following manner:

a. The finely pulverized ore was digested in nitro-muriatic acid till nothing more was taken up.

b. The insoluble residue, consisting of quartz and muriate of silver, was fused with five times its weight of carbonated soda, by which the silver was obtained in the metallic state.

c. The nitro-muriatic solution being concentrated by evaporation, was largely diluted by alcohol, upon which the oxide of tellurium precipitated; and this being re-dissolved in muriatic acid, was obtained in black metallic flocculi, by means of a bar of polished iron.

d. The nitro-muriatic solution *c*, after separation of the tellurium, contained only gold, which was procured by the addition of a solution of green sulphate of iron.

1478. The *yellow ore of Tellurium*, from Nagayag, is composed, according to Klaproth, of

44.75	tellurium
26.75	gold
19.50	lead
8.50	silver
0.50	sulphur
100.	

He performed the analysis of this ore nearly as follows :

a. 400 grains of the pulverized ore were digested with nitric acid, till every thing soluble in this fluid had been taken up.

b. The nitrous solution was combined with muriatic acid, as long as any precipitation took place ; by this there was obtained 51 grains of a white powder, of which 43 grains were again resoluble in boiling water. The insoluble portion, amounting to 8 grains, was muriated silver.

c. The solution, containing the 43 grains above-mentioned, was concentrated by gradual evaporation, and afforded delicate needle-form crystals of muriated lead.

d. The residue of *a*, insoluble in nitric acid, was then treated with nitro-muriatic acid, as long as any thing was taken up; the solution was mixed with the nitro-muriatic solution *b*, and reduced by evaporation till it ceased to deposit muriate of lead. 11 grains were thus obtained.

e. To the concentrated solution *d*, was added caustic potash in excess, which threw down a copious blackish-brown precipitate ; this being separated, the alcaline liquor was saturated with muriatic acid, and the white precipitate thus obtained, being again dissolved in muriatic acid, and then precipitated by means of a stick of zinc, afforded 85 grains of metallic tellurium.

f. The blackish-brown precipitate of *e* was dissolved in nitro-muriatic acid, and the liquor was nearly saturated with caustic potash ; nitrated mercury was then added, till the precipitate began to be white ; this precipitate being separated by the filter, and washed, the filter, with its contents, was ignited in a crucible, and a little nitre being added, the fire was increased, and a button of pure gold was thus obtained, weighing 50.75 grains.

g. The remainder of the nitro-muriatic solution *f* was saturated with carbonated potash, and a precipitate was obtained, consisting of oxide of manganese, mixed with carbonated lime, and a little alumine and oxide of iron.

h. The insoluble residue of *d*, weighing 120.5 grains, and consisting chiefly of quartz, was gently heated, by which it lost about 1 grain, which was sulphur ; being then mixed with four times its weight of carbonated potash, and fused, there was obtained a button of silver, weighing 10.125 grains.

1479. The *black ore of Tellurium*, also from Nagayag, according to the same analyst consists of

54.0	lead
39.2	tellurium
9.0	gold
0.5	silver
1.3	copper
3.0	sulphur
100.0	

This ore was analyzed in the following manner:

a. 1000 grains of the pulverized ore were digested with 10 ounces of muriatic acid, to which was added, by degrees, a little nitric acid; this being poured off, 5 ounces more of muriatic acid were added, by which every thing soluble in this menstruum was taken up; to the filtered solution boiling water was added, to re-dissolve the muriate of lead which had begun to be deposited.

b. Of the insoluble residue a part had cohered into a mass, and was for the most part sulphur, weighing 17.5 grains; being gently ignited, it left behind 3.5 grains of a blackish matter, which was dissolved in muriatic acid, and added to the foregoing solution. Hence the sulphur of the ore amounted to 14 grains.

c. The remainder of the insoluble residue was for the most part quartz, and weighed 440.5 grains. Being melted with four times its weight of carbonated potash there appeared, on breaking the mass, a few globules of silver, amounting to about 2.5 grains equivalent to 3.5 grains of muriated silver; so that the quartzose matrix was equal to 437 grains.

d. The solution *a* being concentrated by evaporation, crystals of muriated lead were deposited, to the amount of 330 grains, equivalent to 248 of metallic lead.

e. Having thus separated the lead, the remainder of the solution was largely diluted with alcohol, by which a white oxide of tellurium was thrown down; this oxide being re-dissolved by muriatic acid, and again precipitated by caustic soda, afforded 178 grains of oxide, equivalent to 148 grains of reguline tellurium.

f. The alcoholic solution was next distilled, by which the alcohol was separated; the residual fluid being diluted with water, was treated with nitrate of mercury, in the way already described, by which a button of gold weighing 41.5 grains was obtained.

g. The residual fluid of *f* was saturated with carbonated soda, and boiled, by which a bluish-grey precipitate was obtained; by digestion in muriatic acid it dissolved, and oxy-muriatic acid gas was produced; the muriatic solution being then supersaturated with carbonated ammonia, there was deposited carbonated manganese, mixed with iron, to the amount of 92 grains.

h. The ammoniacal solution was of a blue colour, upon which it was supersaturated with sulphuric acid, and a plate of iron being immersed in the fluid there were deposited 6 grains of copper.

The above abridged account of Klaproth's analyses of the ores of tellurium is extracted from Messrs. AIKIN's *Dictionary*, and contains a variety of instructive details to the student in analytical chemistry.

SECTION XXII. *Of the Combinations of Selenium.*

1480. THE compounds of this substance have hitherto been examined by Berzelius only; he discovered it, as has already been stated, in the sulphuret of iron from Fahlun, from which sulphur is obtained for the formation of sulphuric acid; when burned for this purpose, a brown compound remains, which consists of sulphur, and a peculiar substance exhaling a strong smell of horse-radish when heated by the blow-pipe: this substance, called by its discoverer *Selenium* (from σεληνη, the moon), indicative of its analogy to *Tellurium*, was separated in minute portions from the brown compound by a very tedious analysis, of which the essential part consisted in digesting it to dryness in nitro-muriatic acid, adding water, and filtering; excess of muriate of ammonia, added to the filtered liquid, threw down selenium.

In this state selenium fuses a little above 212°, assuming, when cool, a brown colour, metallic lustre, and crystalline texture.

It combines with two proportions of oxygen, forming an oxide and an acid; the acid consists of 100 selenium + 38 oxygen; if, therefore, we regard it as containing 1 proportional of selenium + 2 of oxygen, the number 42 will represent selenium, and 58 selenic acid. But, according to Berzelius's analyses of the *Seleniate of Baryta*, it is composed of

Selenic acid	100.0
Baryta	137.7

and these numbers give 56.6 as the equivalent of the acid.

1481. Selenium combines with chlorine, forming a volatile yellow compound: its action upon iodine has not been examined. Combined with potassium, and acted on by dilute muriatic acid, a colourless gas is disengaged, somewhat resembling sulphuretted hydrogen in its odour, and extremely irritating: it is soluble in water, reddens vegetable blues, and causes precipitates in metallic solutions. This gas, which is a true *seleniuretted hydrogen*, consists of 1 proportional of selenium + 1 of hydrogen.

1482. *Sulphuret of Selenium* is an orange-coloured compound, formed by passing sulphuretted hydrogen gas through a solution of selenic acid in water. It appears to be a *sesqui-sulphuret*, containing 3 proportionals of sulphur + 2 of selenium.

1483. *Phosphuret of Selenium* is a fusible brown compound, which has not been analyzed.—BERZELIUS. *Annales de Chemie et Physique*, ix. *Annals of Philosophy*, xiii. THOMSON'S *System*, 6th Edit., i. 297.

1484. The following analysis of a supposed ore of tellurium, from Sweden, by Berzelius, and in which he discovered selenium, I subjoin as an example of his method of proceeding (CHILDREN'S *Translation of* THENARD *on Analysis*, 408.):

a. 100 parts of the purest portions of the mineral, carefully selected, were dissolved in boiling nitric acid, the solution diluted with boiling water, and filtered; the clear liquor gave a precipitate with solution of common salt, and the matter which remained on the filter was washed with boiling diluted nitric acid, as long as the washings were rendered turbid by solution of sea-salt.

The chloride of silver, after being washed, dried, and fused, weighed 50.7 parts, equal to 38.93 of silver. The substance remaining on the filter consisted of silica and stony matter, and weighed, after being heated, 4 parts.

b. The liquid from which the silver had been separated was precipitated by sulphuretted hydrogen gas; the precipitate re-dissolved in aqua regia, and the solution concentrated till the nitric acid was entirely decomposed. It was then diluted with water, and sulphite of ammonia added, when the liquid gradually became turbid, and acquired a cinnabar red colour. After some hours it was boiled, and small portions of sulphite of ammonia added from time to time. The boiling was continued two hours, in order to precipitate the whole of the selenium; collected, dried, and heated nearly to fusion on the filter, it weighed 26 parts.

c. From the liquid, separated from the selenium, and deprived of its sulphurous acid by boiling, subcarbonate of potassa threw down a green precipitate, which, when washed, dried, and heated red, was converted into black oxide of copper, and weighed 27 parts, equivalent to 21.55 of copper. This oxide, dissolved in muriatic acid, gave a blue solution, with an excess of ammonia. The alcaline liquor, from which the carbonate of copper had been separated, still retained a greenish tinge; it was concentrated and slightly acidulated with muriatic acid, and a further precipitate of 1.5 part of copper separated by a plate of iron, which makes the whole of the copper 23.05.

d. The liquid, precipitated by sulphuretted hydrogen, (*b*) was deprived of the excess of gas by boiling, and mixed with caustic ammonia, which threw down a yellowish precipitate, weighing, when dried, 1.8 parts, and was a mixture of oxide of iron with a little alumina. The remaining solution was mixed with subcarbonate of potassa in excess, and evaporated to dryness. The saline mass, re-dissolved in water, left a white earth, which, heated red, weighed 3.4 parts. Sulphuric acid, mixed with this earth, occasioned an effervescence, and by evaporation became gelatinous, and deposited silica; it appeared also to contain magnesia, but it was not particularly examined, as these earths were evidently foreign to the ore.

The results of the analysis then are,

Silver	38.93
Copper	23.05
Selenium	26.00
Earthy and foreign substances	8.90
Loss	3.12
	100.00

The loss must be partly attributed to the carbonic acid of the carbonate of lime; still more to selenium, which it is difficult to separate entirely; and partly to the loss unavoidable in this sort of experiments.

Section XXIII. *Of the Combinations of Arsenic.*

1485. The method of separating arsenic from some of its combinations, and estimating its quantity has already been adverted to; some further account of the process, and of the analysis of arsenical combinations remains to be given in this section.

Where the object is merely to drive off the arsenic contained in any ore, it may be effected by reducing it to powder, mixing it with sawdust, or charcoal, and applying a dull red heat for some hours; the carbonaceous material, by keeping the arsenic in the metallic state facilitates its escape in the form of vapour, and by dividing the material, prevents its running into lumps by partial fusion.

1486. To estimate the quantity of iron in the *arsenical pyrites*, Messrs. Aikins advise the following as a short and convenient process: "Add to the powdered ore dilute nitric acid, and digest in a gentle heat; this will dissolve all the arsenic and iron, whilst most of the sulphur, with the siliceous residue, will remain undissolved. Pour off the nitrated solution, mix with it about twice as much powdered charcoal as the quantity of ore employed, and evaporate nearly to dryness; put the residue into a tall crucible, and apply a brisk red heat for about ten minutes, by which time the arsenic will be almost entirely driven off in copious fumes, and the residue will consist of little else than charcoal and oxide of iron. Spread this upon a heated tile, till the charcoal is almost burned off by which any arsenic still adhering will be dissipated, and the remaining oxide of iron may be reduced, or estimated as mentioned under that metal. The nitrous acid is preferable to the muriatic in this process, as the latter, when strongly heated, volatilizes part of the iron, and renders the assay incorrect."—*Dictionary*, i. 95.

1487. In the analysis of ores containing arsenic, the most certain method of estimating its quantity, consists in acidifying it by nitric acid; the arsenic acid may then be thrown down, *with due precautions*, by nitrate of lead, and the proportion of arsenic deduced from that of the arseniate of lead; the following process, for instance, may be followed in the analysis of the *sulphuret of arsenic and iron* (1059):

a. Digest 100 grains of the ore in fine powder, in nitric acid, a little diluted, so as sufficiently to moderate its action; a portion of sulphur will remain undissolved, together with silica, if any be present, which may be separated, washed, and burned, in order to obtain the silica.

b. The acid solution containing nitric, sulphuric, and arsenic acids, and oxide of iron, may now be supersaturated with solution of soda, and the precipitate boiled in the alcaline liquor, which, being filtered off, leaves peroxide of iron, by which, when dried and ignited, the equivalent of the metallic iron in the ore is obtained.

c. Neutralize the filtered alcaline liquor with nitric acid, and pour in nitrate of lead, which will give a precipitate of sulphate of lead and arseniate of lead; collect and wash it, and digest it in dilute nitric acid, which will take up the arseniate, but leave the sulphate of lead; the arseniate may again be obtained by saturating with soda.

d. Estimate the sulphur in the sulphate of lead, and add it to that procured by process *a*. 100 parts of the arseniate of lead are equivalent to 56.5 of metallic arsenic.

1488. Mr. Chenevix, in the *Philosophical Transactions* for 1801, has given some valuable details respecting the analysis of several ores of copper; the *native arseniate of copper* (1038) he examined as follows:

The ore was first heated to expel and estimate the water; it was then digested in dilute nitric acid, and nitrate of lead poured in, to form arseniate of lead, part of which being held in solution by excess of nitric acid, the liquor was evaporated nearly to dryness, and alcohol added, which occasioned the complete separation of the whole of the arseniate of lead; the remaining solution containing the copper was then boiled with potassa and the oxide of copper collected.

1489. *Pharmacolite*, or *Native Arseniate of Lime*, was submitted to the following satisfactory analysis by Klaproth.—*Essays*, ii. 221.

a. 100 grains lost, by being moderately heated in a porcelain crucible 22½ grains. As in this operation, neither by the smell nor by the sight, any volatilization of any principle could be observed, this loss of weight must have been caused by the escaping of the water of crystallization. On the other hand, the specimens had undergone no other change by this heating, except their surface being rendered a little duller. But the places spotted red from the cobaltic crust, had now assumed a light-bluish colour.

b. Those 77½ grains which remained after the ignition, dissolved in nitric acid, leaving a grey residue of 6 grains of siliceous, mixed with argillaceous, earth.

c. The filtered nitric solution, which somewhat inclined to the reddish, was evaporated to a smaller volume, and mixed with a solution of acetate of lead as long as any precipitation ensued. The precipitate, when collected, washed and dried at a raised temperature, weighed 138 grains. It consisted of arseniated lead, = 46.5 grains arsenic acid.

d. What remained of the fluid after the separation of the precipitate, together with the washings (*c*) was evaporated to some degree, during which green-coloured borders appeared on the inner surface of the vessel. In order to separate the small quantity of undecomposed acetate of lead, it might yet have contained, I added the requisite quantity of muriatic acid. When, upon farther evaporation no muriate of lead any longer appeared, I mixed the fluid with sulphuric acid. This produced a copious precipitate of sulphated lime, which being collected on the filter, washed with weak spirit of wine and heated to redness, weighed 54 grains. Therefore, since in 100 parts of ignited gypsum the pure calcareous earth amounts to 42½ parts, the mentioned 54 grains determine the portion of lime contained in the fossil examined at 23 grains.

e. The remainder of the liquor was neutralized with carbonate of soda, and reduced to the state of siccity. On re-dissolving in water the dry saline mass, there remained a powder of the colour of flax-blossoms, and ½ grain of weight, which tinged the borax-glass with a fine deep blue, and thus proved to be an oxide of cobalt.

Those 100 grains of pharmacolite, submitted to this analysis, have, therefore, been decomposed into

Acid of arsenic	46.50
Lime	23
Oxide of cobalt	0.50
Aluminous silex	6.
Water	22.50
	98.50

But since the cobaltic oxide is here but casually admixed, as also the siliceous earth originates merely from the granitic matrix, it follows that, after subtracting these, the proportions of the constituent parts in the pure pharmacolite, are,

Acid of arsenic	50.54
Lime	25
Water	24.46
	100.

◆

Section XXIV. *Of the Combinations of Molybdenum.*

1490. The *native Molybdate of Lead* (1076) was analyzed nearly as follows by Mr. Hatchett:

a. The iron and molybdic acid were separated by the action of hot sulphuric acid; the silica and lead (in the state of sulphate,) were left undissolved.

b. The acid liquor, saturated by ammonia, deposited oxide of iron, which being separated, the whole was evaporated to dryness, and heated to drive off sulphate of ammonia, and the dry residue was pure molybdic acid.

c. The undissolved residue of *a* was boiled with carbonate of soda, and afterwards digested in dilute nitric acid: the carbonate of lead was dissolved, and the silica remained.

d. The nitrate of lead was decomposed by sulphuric acid, and when the sulphate of lead had been separated, the residual liquid was saturated with ammonia, which threw down a small additional portion of oxide of iron.

The results of this analysis were,

Molybdic acid	38.00
Oxide of lead	58.40
Oxide of iron	2.08
Silica	0.28
	98.76

1491. The analysis of the *sulphuret of molybdenum* may be performed by the action of nitric acid, which separates part of the sulphur, and acidifies the remainder as well as the molybdenum; the quantity of sulphur being ascertained by weighing the separated portion, and precipitating by nitrate of baryta that which is acidified, the loss of weight gives the proportion of molybdenum, and the excess of weight of the molybdic acid, above the deficiency, gives the proportion of oxygen united to the molybdenum to constitute molybdic acid. According to Bucholz, the sulphuret of molybdenum is composed of

Molybdenum	60
Sulphur	40
	100

These numbers nearly correspond with the preceding estimate of the composition of this ore (1078); and if we consider it as a bi-sulphuret, it will consist of

1 Proportional of molybdenum . . . . = 47
2 . . . . sulphur . . . . . . 16 × 2 = 32
79

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SECTION XXV. *Of the Combinations of Chromium.*

1492. Two methods of analyzing *Chromate of Lead* (1088) have been pointed out by Vauquelin (*Journal des Mines*, No. 34.) The first consists in repeatedly boiling the finely powdered ore in solution of carbonate of potassa, by which carbonate of lead and chromate of potassa are formed; and the second, by digesting it in muriatic acid, by which muriate of lead is produced, and the chromic acid obtained dissolved in the excess of muriatic acid.

1493. *Chromate of Iron* (1087) is a more refractory compound, but it may be decomposed by the alternate action of potassa and muriatic acid (*Journal des Mines*, No. 55.) The ore, in fine powder, should be heated red hot, with its weight of caustic potassa, for an hour, and the residue washed with water. The insoluble portion may then be boiled in muriatic acid, and, when no longer acted upon, washed, dried, and ignited as before; by the alternation of these processes, it will ultimately be resolved into an alcaline and acid solution; the former, neutralized by nitric acid, lets fall a portion of alumina and of silica, and holds chromate of potassa in solution; add to it nitrate of lead, by which chromate of lead is thrown down, and may be decomposed by muriatic acid. The muriatic solution, evaporated and diluted, lets fall silica, and ammonia throws down oxide of iron and alumina, which may be separated by potassa; evaporate to dryness, and heat to separate muriate of ammonia; the chromic acid remains.

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SECTION XXVI. *Of the Combinations of Tungsten.*

1494. *a.* To ascertain the component parts of *Tungstate of Lime*, (1093) Klaproth digested 100 grains of it in fine powder with hot nitric acid, and then decanted the supernatant liquor from the yellow residue; upon which last, after edulcoration, he poured liquid ammonia, and put it in a moderately warm place. This alcali took up that portion of the tungstic oxide, which had been set free by the nitric acid; and thus caused the yellow colour to disappear. The residue was treated twice more, by nitric acid and ammonia. In this way the total decomposition of the fossil was effected; so that only 2 grains of silica remained.

b. The nitric solution was then neutralized with ammonia. But as no change ensued, it was precipitated, in a boiling heat, with carbonated soda; and the precipitate washed and dried. It weighed 33 grains, and consisted of carbonate of lime, which, however, on re-dissolution in weak nitric acid, deposited 1 grain of silica. 33 grains of carbonate of lime are equivalent to 17.60 grains of lime.

c. The ammoniacal solution afforded, by evaporation in a low heat, slender needle-shaped crystals.' When thoroughly desiccated the mass was ignited in a platinum crucible. The tungstic oxide which then remained had the form of a heavy, greenish-yellow powder, and weighed 77¾ grains.

Consequently the 100 grains of tungstate of lime have afforded

Yellow oxide of tungsten (tungstic acid)	77.75
Lime	17.60
Silica	3.
	98.35

1495. The examination of *wolfram* (1092) has not as yet been very satisfactorily accomplished, but the analysis of Messrs. D'Elhuyars is probably not far from the truth (*Mémoires de l'Acad. de Toulouse*, ii.) Their result is as follows:

Tungstic acid	64.0
Oxide of manganese	22.0
Oxide of Iron	13.5
	99.5

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SECTION XXVII. *Of the Combinations of Columbium.*

1496. THE original analysis of the *Columbite* (1102) from North America, by Mr. Hatchett, is detailed in his paper in the *Phil. Trans.* for 1802.

This mineral, which is a compound of the oxides of columbium, iron, and manganese, was rendered soluble by the alternate action of fused carbonate of potassa and muriatic acid; the muriatic solutions contain the iron and manganese, and the columbium is retained in combination with the potassa, from which it may be precipitated by nitric acid.

Dr. Wollaston in his experiments to show the identity of columbium and tantalum (*Phil. Trans.* 1809,) mixed 5 parts of the ore with 25 of carbonate of potassa, and 10 of borax. The resulting mass was softened with water and digested in excess of muriatic acid, which took up every thing, except the oxide of columbium. The muriatic solution was neutralized with carbonate of ammonia; and the iron separated by succinate of ammonia; after which the manganese was separated by prussiate of potassa. The results of this analysis are given above (1090.)

SECTION XXVIII. *Of the Combinations of Nickel.*

1497. THE separation of nickel from cobalt has already been described (1466) and the analysis of meteoric iron has also been elsewhere adverted to (1126). It remains here to give a general formula for the analysis of ores containing nickel, which is often rendered extremely complex, from the variety of substances united in some of its ores. The following general directions are extracted from Messrs. AIKIN's *Dictionary* (Art. NICKEL,) and the process has been repeated in the Laboratory of the Royal Institution with sufficiently satisfactory results.

i. The ore being ground to an impalpable powder must be digested with nitric acid considerably diluted; nitrous gas will be given out, and by two or three digestions every thing soluble will be taken up.

ii. The insoluble portion, consisting for the most part of sulphur and silex, is to be dried, weighed, and then heated; the sulphur (*a*) will burn off, and its amount may be ascertained by the difference of weight before and after ignition. The residue after being boiled in a little nitric acid is pure silex (*b*).

iii. Add together both the nitric solutions, nearly saturate the liquor with pure soda, evaporate it considerably, and then pour the solution into cold distilled water, by which the oxide of bismuth (*c*) will be precipitated.

iv. To the filtered solution add muriate of soda drop by drop as long as any precipitate falls down; this is muriate of silver (*d*).

v. Now evaporate the solution nearly to dryness, and boil it with strong nitric acid as long as any nitrous gas is given out: during the process red oxide of iron (*e*) will be precipitated.

vi. Having removed the oxide of iron, nearly saturate the liquor with soda, and pour in nitrate of lead as long as any arseniate of lead (*f*) is precipitated, which separate by the filter.

vii. The nitrous solution being now decomposed by carbonated soda, and the washed precipitate digested in liquid ammonia, oxide of iron (*g*) mixed with alumine (*h*) will be left behind, which may be separated in the usual way by potassa.

viii. The ammoniacal solution is to be slightly supersaturated with nitric acid, and a bar of iron being immersed in it will separate the copper (*i*); after which the liquor is to be decomposed by carbonated soda, and the precipitate again digested in ammonia, that the iron used for separating the copper may be got rid of.

ix. The solution, containing now only nickel and cobalt, is to be treated according to Mr. R. Phillips's (*Phil. Mag.* xvi. p. 312,) method as follows: Evaporate the liquor till the excess of ammonia is driven off, which may be known by the vapour ceasing to discolour moist turmeric paper; then largely dilute it, and pour in pure potash or soda, as long as any precipitation takes place; what falls down is oxide of nickel (*k*).

x The cobalt (*l*) alone remains in solution, and may be readily separated, by accurately saturating the liquor with nitric acid, and then adding carbonated soda.

The above general mode of proceeding is also applicable to the analysis of *nickel ochre*, except that it should first of all be digested in water, to dissolve out any sulphate of nickel which it may accidentally contain.

1498. The results of the following analysis of the *crystallized sulphate of nickel*, which was made with a view to verify the equivalent number of the metal, are given above (1125).

a. 100 grains of the crystals were heated in a porcelain crucible, to dull redness, for ten minutes; they crumbled into a pale green powder, perfectly soluble in water, consequently no acid had been expelled, and lost 45 grains = water of crystallization.

b. The remaining 55 grains of dry salt were dissolved in two ounces of water, to which nitrate of baryta was added, as long as it occasioned a precipitation; the sulphate of baryta thus formed being collected, washed, dried, ignited, and weighed, amounted to 83 grains = 28.25 sulphuric acid.

c. The filtered solution from which the sulphuric acid had been thrown drown in the last process, was now mixed with a little sulphate of soda, to separate excess of baryta, filtered, concentrated by evaporating, and rendered alcaline by potassa; the precipitated oxide of nickel was then thoroughly edulcorated, dried, and exposed to a dull red heat, till it ceased to loose weight; it amounted to 26.5 grains.

The salt, therefore, was thus decomposed into

Water of crystallization	45.00
Sulphuric acid	28.25
Oxide of nickel	26.50
	99.75

SECTION XXIX. *Of the Combinations of Mercury.*

1499. WHAT is termed *native mercury* is usually an amalgam, containing a variable portion of silver, and often a trace of gold; it may be analyzed by exposure to heat, which dissipates the mercury, leaving silver and gold, separable by the action of dilute nitric acid.

If the amalgam, besides gold and silver, contain bismuth, its quantity may be judged of by solution in nitric acid, concentration by heat, and pouring the solution into a large quantity of pure water, by which the greater part of the bismuth will be thrown down in the form of white oxide; but the analysis of complex amalgams is much simplified by previously expelling the mercury by heat, taking care that no other metal evaporates with it, which is sometimes the case at high temperatures.

1500. The analysis of *Native Cinnabar* (1182) may be effected in the following manner:

a. Reduce it to powder, and digest it in a sand heat with dilute nitric acid; wash the insoluble portion with hot water, and add the washings to the nitric solution; sulphur will thus be separated, which may be dried and weighed; it may possibly contain silica, and a little oxide of iron; if so, these are left after the combustion of the sulphur, and may be separated by dilute muriatic acid.

b. Add carbonate of potassa in excess to the nitric solution, collect and dry the precipitate, having previously boiled it for a minute or two in the alcaline liquor, and mix it with a little charcoal: put the mixture into a small coated retort, and at a red heat the mercury may be distilled over; the residue may be examined for alumina, lime, oxide of iron, or other extraneous matters.

1501. The *Native Murio-sulphate of Mercury* (1156) may be dissolved in acetic acid, by which a portion of metallic mercury is usually separable from it; nitrate of baryta, added to the acetic solution, separates the sulphuric acid in the state of sulphate of baryta, which being removed, nitrate of silver will throw down chloride of silver; immerse a plate of iron into the remaining solution to precipitate metallic mercury, or throw it down by carbonate of potassa, and distil with a little charcoal.

1502. The *assay* of mercurial ores may be effected by mixing the powdered sample with half its weight of a mixture of equal parts of lime and iron filings, and submitting it to distillation in the open fire, in a coated glass retort.

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SECTION XXX. *Of the Combinations of Silver.*

1503. As instances of the analysis of complex silver ores, I have selected that of the bismuthic silver, and of the white silver ore, from Klaproth (*Essays*, i. 556, 145.) whose paper on the composition of various silver ores may be strongly recommended to the attentive perusal of the student.

a. Upon 300 grains of the *Bismuthic Silver* from Schapbach, in the Black Forest, I poured three ounces of nitric acid, diluted with one of water; a great part of it dissolved, even in the cold; the residue was again digested with one ounce of the same acid, in a gentle heat; both solutions were filtered, mixed, and evaporated to a smaller volume; during which process there separated some crystalline grains of nitrate of lead.

b. The concentrated solution had a greenish colour; when diluted with as much water as was requisite to re-dissolve that crystalline sediment, it was poured into a large quantity of water; this immediately acquired a milky appearance, and deposited a white precipitate, which weighed 44.5 grains, when collected, lixiviated, and dried in the air, and proved on further examination to be oxide of bismuth.

c. Into the liquor that had been freed from this oxide, and was clear and colourless, I dropped muriatic acid, as long as it was rendered turbid by it: the precipitate did not appear to be mere muriate of silver, for this reason I digested it with nitric acid; a considerable portion was thus re-dissolved, and left pure horn-silver behind; which, upon careful collection, and desiccation in a brisk heat, weighed 46 grains: thus, the portion of pure silver is determined at 34.5 grains.

d. The nitric acid, that had been affused upon the precipitate obtained by the muriatic *c*, yielded by dilution with much water 32 grains more of oxided bismuth; which, with the preceding 44.5 *b*, gave together 76.5 grains.

e. The remainder of the fluid was farther reduced by evaporation, and in this process muriate of lead separated from it in crystals; this liquor was then combined with such a quantity of sulphuric acid as was requisite to re-dissolve those crystals, and a second time evaporated; the precipitate which thence ensued was sulphate of lead, weighing 19 grains, when duly collected, washed, and dried.

f. What still remained of the solution, after its having been freed from the lead before contained in it, was saturated with caustic ammonia added in excess: in this way a brown ferruginous precipitate was produced which was rapidly attracted by the magnet, and weighed 14 grains, when after previous desiccation, it had been moistened with linseed oil, and well ignited: for these we must reckon 10 grains of metallic iron.

g. The liquor which had been supersaturated with ammonia, and which by its blue colour showed that it held copper in solution, was next saturated to excess with sulphuric acid; on immersing then a piece of polished iron into it, two grains of copper were deposited.

h. The grey residue of the ore, that was left behind by the nitric acid *a* weighed 178 grains; but when its sulphureous part had been deflagrated in a crucible gently heated, it weighed only 140.5 grains; this determines the portion of sulphur at 37.5 grains.

i. These 140.5 grains were digested with 3 ounces of muriatic acid in a heat of ebullition, and this process was repeated once more with 1.5 ounces of the same acid; these solutions, by means of evaporation, yielded muriate of lead in tender spicular, and likewise in broad striated, crystals; which, when again dissolved in the requisite quantity of boiling water, then combined with sulphuric acid, and evaporated, yielded 89 grains of sulphated lead; thus the whole quantity of this sulphate, including the 19 grains mentioned at *e*, amounted to 108 grains; for which, according to comparative experiments, 76 grains of reguline lead must be put in the computation.

k. That portion of the ore examined, which still remained after all the constituent parts before-mentioned have been discovered, consisted merely of the grey quartzose matrix, the weight of which, in the ignited state amounted to 70 grains.

Therefore those 300 grains of bismuthic silver ore mentioned above were decomposed into

Lead, *i*	76.
Bismuth *d*	62.20
Silver, *c*	34.50
Iron, *f*	10.
Copper *g*	2.
Sulphur, *h*	37.50
Quartzose matrix, *k*	70.
	292.20

It follows, from this statement, that, exclusively of the quartzose gangue, the constituent parts of the bismuthic silver are in the 100,

Lead	33.
Bismuth	27.
Silver	15.
Iron	4.30
Copper	0.90
Sulphur	16.30
	96.50

1504. Klaproth treated the *white silver ore* from Freyberg, nearly as follows:

a. The ore was brittle, and easily levigated into a blackish powder.

b. Upon 400 grains in powder he poured 4 ounces of nitric acid, and 2 of water; after sufficient digestion in a gentle heat, the solution was decanted, and the residue again treated with 2 ounces of the acid; this mixture was next diluted with eight parts of water, and digested for some time; he then separated the undissolved residue, consisting of a greyish-white powder, which, after washing and drying, weighed 326 grains.

c. The solution, which was nearly colourless, was combined with common salt, by which muriated silver was produced; and the next day crystals of muriate of lead were found; on this, therefore, he boiled the whole precipitate in a large quantity of water, by means of which the muriated lead was re-dissolved, and separated from the muriate of silver, collected on the filter: this last, when reduced by fusion with soda, yielded 81.5 grains of reguline silver.

d. What remained of the solution, together with the liquor obtained by the decoction of the horn silver, he evaporated in part; and by adding a saturated solution of sulphate of soda, obtained from it 45 grains of sulphate of lead, which, upon reduction, afforded 32 grains of lead in the metallic state.

e. The remaining part of the solution was saturated with pure ammonia, upon which a light-brown precipitate fell, weighing 40 grains, when edulcorated and ignited in a low heat; as that precipitate had the appearance of a mixture of iron and alumina, he dissolved it again in nitric acid, and precipitated first the iron by prussiate of potassa, and afterwards, by the addition of soda, a loose earth, which, when desiccated and ignited, weighed 28 grains, and upon trial with sulphuric acid, was found to be aluminous earth; this being subtracted from the above 40 grains, leaves 12 for the oxide of iron, which may be estimated at 9 grains of metallic iron.

f. After this the residue that remained from the solution of the ore, dissolved in nitric acid *b*, was subjected to a closer examination: Klaproth attempted to decompose it by muriatic acid, repeatedly poured upon it, and in every instance digested over it in a heat of ebullition. The process was rendered somewhat difficult by the crystals, which were deposited from the solution as soon as the heat fell below the boiling point; similar crystals likewise shot on the paper, through which the solution, though yet boiling, was filtered, and he gradually re-dissolved them in warm muriatic acid; at last there remained 51 grains of sulphur, leaving, after deflagration upon a test, two grains of a grey residue, one of which dissolved in muriatic acid, and was added to the preceding solution; the other grain was siliceous earth. The true quantity of the sulphur, therefore, amounted to 49 grains.

g. While the muriatic solution was cooling, it deposited a quantity of acicular crystals; these being separated, one half of the remaining fluid was distilled over in a small retort, and from the solution thus concentrated more crystals similar to the first were deposited; this treatment was continued until no more crystals would form; when these crystals, collected together, were mingled with twice their weight of black flux, and reduced in an assay-crucible, thinly lined with charcoal-dust, they afforded 160¼ grains of lead; this lead, subjected to cupellation, emitted at the first application of heat a few antimonial vapours; it then fined quietly, and left a button of silver, weighing ⅛ of a grain; this determines the proportion of lead at 160.25 grains; from which, however, a trifling quantity should be deducted for the portion of antimony before-mentioned, though it could not be well determined, besides that it could not weigh much above half a grain.

h. The fluid separated from the muriate of lead, concentrated, and diluted with a large quantity of water, deposited its metallic part, which, in the form of a subtle white powder, was only oxide of antimony, and being kneaded into a mass with soap, was reduced in a luted assaying-crucible, by means of black flux, into 28.5 grains of pure reguline antimony; some more small globules were found adhering to the lid of the vessel, of which I collected 3 grains; but still a small portion appeared to have escaped through the joinings, and for this reason, the true amount of antimony which I obtained may be reckoned at somewhat more than the 31.5 grains.

Hence the product of the 400 grains of the white silver ore here analyzed consisted of

Silver . . .	*c*	81½	81⅝ grs.
	g	⅛	
Lead	*d*	32	192¼
	g	160¼	
Reguline antimony *h*			31½
Iron, *e*			9
Sulphur, *f*			49
Alumina, *e*			28
Silex, *f*			1
			392⅞

Which in 100 parts makes

Silver	20.40
Lead	48.06
Antimony	7.88
Iron	2.25
Sulphur	12.25
Alumine	7.
Silex	0.25
	98.09

SECTION XXXI. *Of the Combinations of Gold.*

1505. In the Section on the combinations of Tellurium, I have quoted Klaproth's analyses of some of its ores containing gold; the only proper ore of this metal is *native gold*, (1275) which is occasionally found in veins, but of which by far the greatest proportion occurs dispersed in a granular form through certain alluvial strata In this state, silver and copper are the principal metals with which it is combined, and the analysis is sufficiently simple; the ore may be digested in nitro-muriatic acid; the solution evaporated nearly to dryness, and again diluted, leaves the silver in the state of chloride; a strong solution of proto-sulphate of iron may then be used to throw down the gold (1276), and the copper may be separated by immersing a plate of iron into the last filtered liquor.

If the proportion of silver and copper alloyed with the gold be considerable, the analysis may be simplified by using nitric acid in the first instance, which extracts the silver and copper, leaving the gold untouched: muriatic acid may then be poured in, to throw down the silver, and the copper separated by iron, as before; or by precipitation by potassa, and ignition, which gives it in the state of peroxide.

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SECTION XXXII. *Of the Combinations of Platinum.*

1506 WE are indebted to Dr. Wollaston and to Mr Tennant (*Phil. Trans.* 1803) for our knowledge of the component parts of the *ore of platinum*, as imported from South America. In this state it generally contains the following metals, exclusive of small particles of silica, and a variable portion of mercury, *viz.*: platinum, gold, palladium, rhodium, iridium, osmium, iron, copper, and lead; and the following is the process for their separation:

The mercury may be driven off by heat, a process which renders the platinum yellower in consequence of the appearance of the grains of gold; it may then be digested in nitro-muriatic acid diluted with its bulk of water, which takes up gold, iron, and a little platinum; if the remaining ore be now digested in nitro-muriatic acid by far the largest portion will be dissolved, and there will remain a black powder: to the nitro-muriatic liquor add a solution of muriate of ammonia, which will occasion the separation of the greater part of the platinum in the state of a very difficultly soluble ammonio-muriate, and which may be separated upon a filter; in the filtrated liquor immerse a plate of zinc, which will throw down lead, rhodium, palladium, and a portion of platinum; the lead may be separated by very dilute nitric acid; dissolve the residue in nitro-muriatic acid, add common salt, and evaporate to dryness; this residue, composed of the *soda-muriates of platinum, palladium, and rhodium*, is to be digested in alcohol, which dissolves the triple salts of platinum and palladium, but not that of rhodium (1213), which therefore is thus separated; to the alcoholic solution add solution of muriate of ammonia, which throws down the platinum, and leaves the palladium in solution, which may be precipitated by ferrocyanate of potassa (1216).

The insoluble black powder, by alternate fusions with potassa, and boiling in muriatic acid is resolved into *osmium* (1206) soluble in the alcali, and *iridium* (1209) in the acid.

SECTION XXXIII. *Of Siliceous and Aluminous Combinations.*

1507. THE ready solubility of silica by fusion with the fixed alcalis, and its insolubility in the greater number of the acids, render its separation in most cases of analysis extremely easy. Muriatic acid, under certain circumstances, is capable of retaining a considerable quantity of silica, and the solution, when evaporated, assumes a gelatinous appearance; if ammonia be then added, and the whole evaporated and heated red-hot, the silica is obtained pure, and not again soluble in the acid.

1508. Alumina, like silica, is soluble in potassa, and the addition of acids to the mixed alcaline solution throws down a compound which is not entirely decomposed by the action of those acids, which, under ordinary circumstances, readily dissolve alumina without acting upon silica; a circumstance of which it is necessary to be aware, in certain cases of analysis.

1509. If silica is predominant in a stone, it is in general rendered easily soluble by heating it in fine powder with potassa; but there are some of the hard aluminous compounds which are very difficultly acted on in this way; Mr. Chenevix found minerals of this class were most readily attacked by borax. One part of the mineral in fine powder, mixed with about three parts of glass of borax is to be strongly heated in a platinum crucible; the contents, when cold, are perfectly soluble by long digestion in muriatic acid; the addition of carbonate of ammonia throws down the dissolved earths, which may be collected, re-dissolved and examined as usual. Sir H. Davy has, in similar cases, recommended the use of boracic acid.—*Phil. Trans.* 1805.

1510. There are a few minerals which contain fluorine, or fluoric acid, (646) the presence of which is ascertained by heating the substance in fine powder with sulphuric acid, either before or after its fusion with potassa, when vapours which act upon and corrode glass will be liberated. To ascertain the proportion of fluoric acid in a mineral, it may be fused with potassa, and treated by muriatic acid, to separate silica; to the remaining liquid add excess of carbonate of potassa, and filter, neutralize the filtrated liquor with muriatic acid, and add muriate of lime, which will occasion a precipitate of fluate of lime, the purity of which is to be ascertained, and the quantity of fluorine and fluoric acid inferred from it.

1511. Boracic acid, originally found in the *Boracite* (696) by Westrumb, has also been discovered by Klaproth in *Datolite* (xxiv. p. 319.) and in *Botryolite*, and more lately by Arfwedson and Berzelius in the *green Tourmaline* and *Rubelite*. The following is a sketch of M. Arfwedson's analysis.

A portion of the green tourmaline in fine powder, was strongly heated for an hour, with four times its weight of carbonate of baryta; the mass was dissolved in muriatic acid, and the solution evaporated to dryness; water, acidulated with muriatic acid, then dissolved every thing but the silica.

The baryta was separated from the solution by sulphuric acid, and the other earths, with the oxides of iron and manganese, by an excess of carbonate of ammonia; the solution being separated from the precipitate, and evaporated to dryness, a sulphate was obtained, which, when again treated with ammonia as before, dried, and heated red, redissolved in water without leaving any residuum; this solution was freed from its sulphuric acid, by acetate of baryta, and the filtered liquid evaporated; a gummy mass was obtained, which, by calcination in a platinum crucible, was decomposed, and afforded a fused alcaline mass, which proved to be lithia. "I began to consider my work almost finished, (adds Mr. Arfwedson) when, on drying and heating a portion of the alcaline solution, I observed, at the moment the mass began to fuse, that it swelled up like borax, and left a glass, after calcination, of the same appearance as vitrified borax; it was very probable, therefore, that the mineral contained boracic acid, and I ascertained it by heating the fused mass with muriatic acid, which gave me, by evaporation, a salt, partly soluble in alcohol, to which it imparted the property of burning with the greenish flame so characteristic of boracic acid."

To obtain the quantity of this acid, a portion of the mineral was fused with bi-sulphate of potassa; the mass boiled with alcohol, and the filtered liquid evaporated to dryness; a substance remained equal to 1.1 *per cent.* of the weight of the tourmaline, and having all the properties of boracic acid.—*Annales de Chimie*, Vol. x., p. 98.

1512. To the above observations, I shall add, as specimens of practical analysis, two instances from KLAPROTH's *Essays*, *viz.*, his analysis of the *Spinell* and of *Kryolite*:

a. 100 grains of rough spinell from Ceylon, in picked crystals, previously pounded to a coarse powder in a steel mortar, were triturated with water to an impalpable powder in a grinding-dish made of flint; after the powder of the stone, which was again dried, had been gently ignited, it showed an increase of weight of nine grains, arising from the particles abraded from the substance of the grinding-vessel.

b. I then digested the powder with two ounces of muriatic acid; when the acid was evaporated nearly to dryness, I diluted the mass with water, threw it upon the filter, and saturated the yellow muriatic solution with caustic ammonia; a brown flocculent oxide of iron fell down, which, collected and ignited, weighed 1.25 grains.

c. The liquor separated from that precipitate was concentrated by evaporation, perfectly neutralized with muriatic acid, and lastly combined with dissolved oxalate of potassa; in consequence of this, oxalate of lime precipitated, which, when carefully collected, and heated to redness in the cavity of a compact piece of charcoal, with the assistance of the blow-pipe, afforded .75 of a grain of lime.

d. Upon the powder of the stone, extracted by the muriatic acid, was poured ten times its quantity of alcaline ley, one half of which consisted of caustic potassa, which mixture being first evaporated to dryness in a silver vessel, was afterwards ignited during the space of an hour; when the mass had been again softened with hot water, it left on the filtering paper 54 grains of a yellow residue when dried in the air.

e. These 54 grains were a second time mixed, and inspissated with a tenfold quantity of the same caustic lixivium, and afterwards ignited; upon which the mass, softened again with water, deposited a residue of a fine pulverulent form, weighing 43 grains when dried in the air.

f. I then neutralized the yellow alcaline solution (*d* and *e*) by means of sulphuric acid, and by affusing more acid, made a clear solution of the precipitate, which then formed; carbonate of potassa added in a boiling state threw down from it a precipitate of a very great bulk, which after edulcoration was again dissolved in sulphuric acid; this solution exhibited a slimy toughness, but it became perfectly fluid, when exposed to a raised temperature, and deposited a subtle white powder, which, after washing and desiccation in the air, weighed 95 grains: the sulphuric acid fluid, when separated from it, was set aside for a time.

g. The above-mentioned 95 grains were then gently ignited with thrice their quantity of caustic potassa; when again liquified with water, and filtered, there remained only a slight residue, which after washing, dissolved in sulphuric acid, with the exception of a few remaining particles.

h. The portion taken up by the potassa in the alcaline solution *g* was precipitated by means of sulphuric acid; but it dissolved again in the acid, when added to excess, and was afterwards precipitated by boiling with carbonated alcali: this precipitate, previously washed, was once more dissolved in sulphuric acid.

i. The whole of the sulphuric solutions, obtained at *f g h*, was evaporated to a smaller compass; the gelatinous consistence into which it congealed showed that a separation of siliceous earth had taken place: it was therefore largely diluted with water, digested, and the silex collected upon the filter.

k. This done, the sulphuric solution was put in a state to crystallize, by dropping into it a solution of acetate of potassa, and evaporating it slowly; it yielded at first regular and pure crystals of alum; but as the solution assumed a green colour towards the end, I combined it with Prussian alcali; a trifling precipitation ensued, of which the oxide of iron could not be estimated more than at one-fourth of a grain; the solution being now freed of its ferruginous ingredient, was next decomposed in a boiling heat by carbonated potassa, and the precipitate, when dissolved anew in sulphuric acid, was brought to a final crystallization, after which the alum then obtained was added to the foregoing.

l. I now proceeded to the analysis of the 43 grains, that were left undissolved by the caustic alcaline ley *e*. These readily dissolved in dilute sulphuric acid, leaving some siliceous earth behind; the solution, separated from this last, was then combined with a small portion of acetated potassa, and exposed to spontaneous crystallization by exhalation in the open air. At first there yet appeared some solitary crystals of alum; but afterwards it entirely shot into sulphate of magnesia (Epsom salt).

m. To separate the sulphated magnesia, thus obtained, from the admixed alum, it was strongly ignited in a porcelain vessel during half an hour, and the saline mass afterwards softened in water, and filtered; the aluminous earth, separated by this management, was afterwards dissolved in sulphuric acid, and in the proper manner crystallized into concrete alum.

n. The pure solution of the sulphated magnesia was precipitated in a boiling heat by means of vegetable alcali. The magnesian earth, thus obtained in a carbonated state, weighed 20 5 grains when washed and dried; but after strong ignition it weighed only 8.25 grains.

o. All the washings (of which that at *f*, on precipitating the sulphuric solution by carbonate of potassa, retained the yellow colour of the first solution) were together evaporated to a dry saline mass; when they had been re-dissolved in water, there still separated a little earth, which, along with the precipitate remaining at *g*, was ignited with caustic potassa, and then by sulphuric acid resolved into aluminous and siliceous earths.

p. The whole quantity of alum, obtained at *k l m* and *o*, amounted to 665 grains. It was now dissolved in water, and in a heat of ebullition decomposed by carbonate of potassa. The aluminous earth thus obtained, when edulcorated with water, and dried in a moderate warmth, weighed 221 grains; but after being purified by digestion with distilled vinegar, and subsequent saturation with ammonia, and being again edulcorated, and at last subjected for half an hour to an intense red heat, it weighed no more than 74.5 grains.

q. I then ignited, for half an hour, the whole of the siliceous earth collected from *i l o*: its weight was 24.5 grains. Hence, subtracting the 9 grains which had been abraded from the flint-mortar *a*, there remained 15.5 grains belonging to the spinell.

From this analysis it follows, that the constituent parts of the spinell in the 100 are

Alumine, *p*		74.50
Silex *q*		15.50
Magnesia, *n*		8.25
Oxide of iron	*b* . . 1.25 *k* . . 0.25	1.50
Lime, *c*		0.75
		100.50

The reason why, in this instance, there appears in the sum of the weights an excess of half a grain, rather than a loss, unavoidable in the usual course of such processes, is probably, that the ignition was not powerful enough to effect in those ingredients that high degree of dryness, which that stone possesses in its natural undecomposed state.

1513. *Analysis of the Kryolite;* after some preliminary experiments, which taught him the existence of fluoric acid, soda, and alumina in this mineral, Klaproth proceeded as follows:

i. 100 grains of triturated kryolite, to expel entirely the fluoric acid, were inspissated to dryness in a platinum crucible, with 300 grains of concentrated sulphuric acid. The residual mass, previously drenched with water, congealed on evaporation to a soft, granular saline mass, which readily liquified in a little water.

ii. Caustic ammonia precipitated from the clear solution the aluminous earth weighing 46 grains, when edulcorated and dried, but 24 grains when ignited. The solution of this earth, in dilute sulphuric acid, with the assistance of heat, and combined with a just proportion of potassa, shot into regular crystals of alum.

iii. The fluid, from which the alumina had been precipitated, was neutralized with acetic acid, then combined with acetated baryta, and filtered, to separate the barytic sulphate, The clear fluid was now wholly evaporated, its dry residuum ignited in a platinum crucible, redissolved, and, after being rendered free by filtration, from the few adhering coaly particles, a second time evaporated to perfect dryness. It thus afforded 62½ grains of dry carbonate of soda, equal to 36 grains of pure soda. This, saturated with acetic acid, crystallized all to acetate of soda.

If now, from the quantity of the fossil employed, be subtracted the weight of alumina and soda obtained, the remainder will give the weight of the fluoric acid, including perhaps the water of crystallization. 100 parts of kryolite, therefore, consist of

Soda	36
Alumina	24
Fluoric acid, including the water	40
	100

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Section XXXIV. *Of the Combinations of Zirconium.*

1514. Klaproth's description of the discovery of zirconia, and of the method of separating it from the Jargon and Hyacinth of Ceylon, contain a very instructive lesson in analytical chemistry; in those minerals the zirconia is combined with silica, and with a trace of *oxide* of iron, the following mode of obtaining pure zirconia, suggested by M. M. Dubois and Silveira (*Annales de Chimie et Phys.* xiv.) furnishes, at the same time, a process for the analysis of the mineral, upon the whole less exceptionable than that of preceding chemists.

Reduce the zircons to fine powder, and heat them in a red heat for an hour, with two parts of pure potassa; pour distilled water on the fused mass, and wash the insoluble portion upon a filter; dissolve it in muriatic acid, and evaporate to dryness; pour water on the residue, which leaves silica, and dissolves muriate of zirconia and iron; filter, and add ammonia, which throws down zirconia and oxide of iron: wash the precipitate and boil it, while moist, in a solution of oxalic acid, which retains the iron, and forms an insoluble oxalate of zirconia; collect and edulcorate the latter, and heat it to redness in a platinum crucible: in this state the zirconia, though pure, is insoluble in acids; fuse it, therefore, with potassa, wash away the alcali, dissolve in muriatic acid, and precipitate by ammonia; the *hydrate of zirconia* now thrown down, when washed and dried, is pure and soluble.

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Section XXXV. *Of the Combinations of Glucinum.*

1515. The composition of the beryl, and of the emerald, and the mode of obtaining from them pure glucina have been given above (1359); in this section therefore I shall merely give Klaproth's examination of the emerald, as showing the mode of separating glucina in analyses.—*Essays*, ii. 177.

a. 100 grains of light-green emerald were levigated in a flint mortar, by which their weight increased 2½ grains. The powder of the stone was mixed with a solution of 250 grains of caustic soda, and inspissated in a silver crucible; upon which the dry mass was moderately ignited during 30 minutes.

b. When this mass had cooled, it appeared white, and not easily softened in water. It was saturated to excess with muriatic acid, which effected a solution. This being evaporated, and afresh diffused in water, was thrown upon the filter, in order to collect the siliceous earth, which, washed, dried, and ignited, weighed 68 grains, after deducting the 2½ grains it received from the mortar.

c. The muriatic solution was supersaturated with soda and boiled. The precipitate was soon again taken up by the fluid, excepting some loose ash-grey flocks, which, upon drying and ignition, weighed 2½ grains. As the filtering paper, upon which this residue has been collected, was coloured brownish, it was extracted with a little weak muriatic acid, and the solution treated with prussian alcali, which produced a blue precipitate of iron.

d. Upon those 2½ grains of the brownish residuum nitric acid was poured and again driven off by heat, after which potassa was affused. This took up but a little, and the residuum, again washed and ignited, lost only $\frac{3}{10}$ of a grain. The alcaline fluid was neutralized with nitric acid, and one-half of it combined with acetated lead, the other half with nitrate of silver. By the lead a lemon-yellow, and by the silver a brown-red precipitate was obtained. Thus the portion of chrome in emerald was separated and obtained singly.

e. The brown residue of *d* was dissolved in muriatic acid, but the solution, acted on by a low heat, soon coagulated into a jelly-like substance, owing to the siliceous earth which separated, and upon ignition weighed ⅓ gr. The fluid, freed from this, was then treated with a solution of succinate of soda. The precipitate, obtained by this means, when edulcorated and dried, gave 1 grain of oxide of iron.

f. As to the alcaline solution *c*, I mixed it with the remaining fluid of *e*, supersaturated the mixture with muriatic acid, and precipitated it in an ebullient heat with carbonated soda. The precipitate here obtained I dissolved in sulphuric acid, and after having combined it with acetate of potassa, forwarded it to crystallization. The first shootings yielded alum, in pure crystals; but on subsequent evaporation sulphate of lime appeared, which, in the ignited state, weighed ¾ of a grain, equivalent to ¼ of pure lime. What still remained of the fluid had now a thick oily consistence; diluted with a little water, and exposed to spontaneous crystallization, it afforded crystals, but they had not the form of alum.

g. This saline mass, together with the alum already obtained, was dissolved in water, and a large quantity of carbonate of ammonia affused, upon which I stoppered the vessel. After it had stood 24 hours, I separated the remaining earth by means of the filter, dissolved this last again in sulphuric acid, and, lastly, extracted it by adding a great over-proportion of carbonated ammonia. When the earth had again been separated, it was a second time subjected to the same treatment; after which nothing more was taken up by the ammonia.

h. The aluminous earth was now heated to redness; it then amounted to 15¾ grains.

i. From the ammoniacal fluid, which had been collected from those reiterated extractions, the superabundant alcali was distilled off, until the quantity of the white earth, which parted from the fluid, no longer increased. This earth, washed and dried, weighed 23¼ grains; after ignition its weight proved to be 12½ grains.

When re-dissolved in sulphuric acid, and left to spontaneous evaporation, it formed oblique, quadrilateral double pyramids, with truncated edges and corners. The saccharine taste of these crystals, in conjunction with their other properties, showed that the base of this salt was glucine, the new earth discovered by Vauquelin in the beryl.

Hence this decomposed emerald has yielded, as its constituent parts,

Silex	*b*	68	68.50
	e	0.50	
Alumine	*h*		15.75
Glucine	*i*		12.50
Lime	*f*		0.25
Oxide of iron	*e*		1
Oxide of chrome	*d*		0.30
			98.30

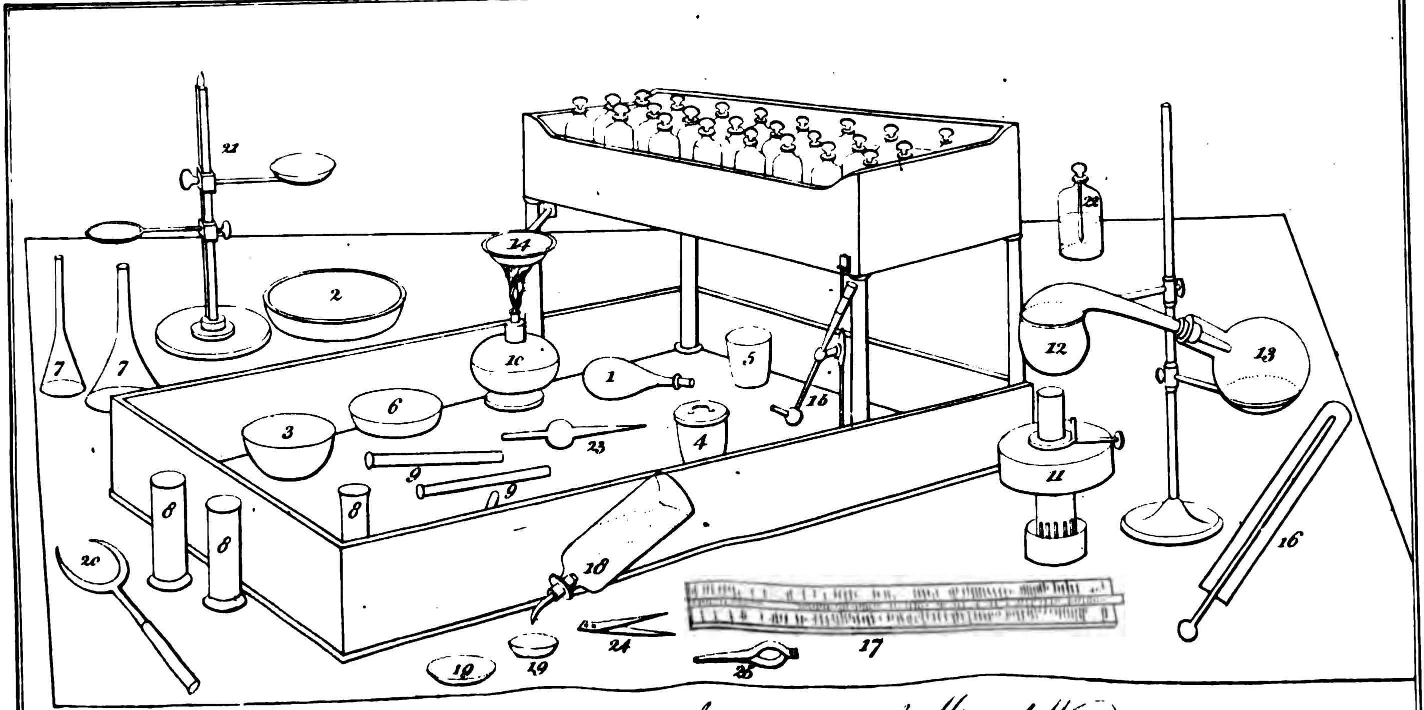
Section XXXVI. *Of the Combinations of Yttrium and Thorinum.*

1516. I have not been able to collect any information relative to the analysis of the compounds containing yttria, which would assist the student in their examination, in addition to that which has been given in the preceeding Chapter, where I have enumerated the distinctive characters of yttria, and the mode of separating it from its combination with other earths (1362).

1517. Thorina, found by Berzelius in the Gadolinite of Korarvet, and in two other Swedish minerals, which he terms *deuto-fluate of cerium*, and *double fluate of cerium and yttria*, has not hitherto been examined by any other chemist; indeed, the discoverer has himself obtained it in such small quantities as to have enabled him to furnish but an imperfect account of its properties. In addition, therefore, to the distinctive characters of thorina given above (1364) I shall here only add the process by which it was procured.

To the solution of the mineral add succinate of ammonia to throw down the iron; then pour in sulphate of potassa to precipitate the cerium, and afterwards ammonia will separate the yttria and thorina; to separate these substances re-dissolve them in muriatic acid, and evaporate till the solution is as nearly neutral as possible, then pour water upon it and boil for an instant; thorina is precipitated, and the liquid becomes acid: by saturating this acid, and boiling again, an additional portion of thorina precipitates.

These details are, it must be confessed, very unsatisfactory: and



Portable Laboratory for the Analysis of Mineral Waters.

when we reflect upon the complex nature of the substances submitted to analysis, upon the prolixity of the process, upon the small quantity of thorina hitherto procured (not amounting, according to Dr. Thomson (*System*, i. 377, 6th *Edit.*) to 7 grains and a half,) and upon the acknowledgment that it is only occasionally present in the minerals adverted to, we may perhaps be inclined to doubt its distinct nature.

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CHAPTER VII.

OF THE ANALYSIS OF MINERAL WATERS.

1518. THE following observations, relating to the analysis of mineral waters, have been drawn up principally with a view to facilitate the progress of the student, in that very difficult department of analytical chemistry. I have endeavoured to simplify the details by pointing out the readiest methods of recognising and separating the substances which usually occur, and have, therefore, omitted the enumeration of the more rare ingredients, or of those which are limited to particular places.

I have not adverted to the mode recommended by Dr. Murray (*Edinburgh Phil. Trans.*, viii.) because I cannot readily admit the existence of incompatible salts to the extent which his principle requires; nor do I think that it materially facilitates the analysis in those cases which present peculiar difficulties to the plan of determining the ingredients by evaporation.

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SECTION I. *Of the Tests and Apparatus required in the Examination and Analysis of Mineral Waters.*

1519. THOSE who have not access to a regular laboratory will find it convenient to arrange the following tests and re-agents in the manner represented in Plate III. of this work, the larger phials should contain about 6 ounces by measure; the second size, 3 ounces; and the smallest, 1 ounce. Of these phials, the greater number should be simply stopped, and a few of them provided with an elongated stopper dipping into the fluid which they contain.

The larger phials may contain the following re-agents;

Pure sulphuric acid.
—— nitric acid.
—— muriatic acid.
Dilute sulphuric acid, 1 acid + 3 water.
—— nitric acid . . . . . ditto.
—— muriatic acid . . . ditto.
Solution of potassa.

Solution of soda.
———— ammonia.
———— carbonate of potassa.
———— carbonate of soda.
———— carbonate of ammonia.
———— oxalic acid.
———— oxalate of ammonia.
———— baryta.
———— acetate of baryta.
———— nitrate of baryta.
———— phosphate of soda.
———— sulphate of silver.
Alcohol.

The smaller phials may contain

Tincture of galls.
Solution of iodine in alcohol.
———— nitrate of silver.
———— ferro-cyanate of potassa.
———— muriate of lime.
———— hydro-sulphuret of ammonia.
———— hydriodate of potassa.
———— soap in alcohol.
Phosphorus.
Sulphate of lime.
Test-papers, turmeric, litmus, violet.
Black flux.
Nitrate of ammonia.

The tray should contain a few Florence flasks (1), Wedgwood and glass basins (2, 3), a platinum and a silver crucible (4, 5), a silver capsule (6), some funnels (7), test-glasses (8), test-tubes (9), and glass rods, filtering paper, a spirit (10), and an Argand lamp (11), a retort (12), and receiver (13), a copper basin to serve as sand-bath (14), a blow-pipe (15), a thermometer (16), a scale of equivalents (17), a dropping-bottle (18), a few watch-glasses (19), a support for holding glasses over a lamp (20), a small brass stand with rings (21), a tube, with a bulb in the centre and a pointed extremity, for drawing up small portions of liquids (23), platinum pincers (24, 25); a small but good balance, with well-adjusted weights, is also requisite, accompanied by a phial and counterpoise for taking specific gravities; and, lastly, a small mercurial trough. There should also be a plentiful supply of distilled water, a portion of which should be contained in a dropping-bottle.

SECTION II. *Examination of Mineral Waters by Tests.*

1520. i. THE term *mineral water* is applied to those natural spring-waters which contain so large a proportion of foreign matter as to render them unfit for common domestic use, and to confer upon them a sensible flavour, and specific action upon the animal frame. Their temperature is liable to considerable variation, and is sometimes their principal character, as is the case with the waters of Bath and Buxton; but they are generally so far impregnated with acid or saline bodies, as to derive from them their peculiarities, and in this respect may conveniently be arranged under the heads of *carbonated*, *sulphureous*, *saline* and *chalybeate* waters. See the annexed Table (1522.) The mere taste of the water enables us to determine to which of these subdivisions it probably belongs.

ii. In examining a mineral water, it is of importance to ascertain its specific gravity, which gives us some insight into the proportion of its saline ingredients, its specific weight, as compared with pure water, being of course augmented by its foreign contents. Mr. Kirwan (*Essay on Mineral Waters*, p. 145.) has given the following formula for calculating the proportion of saline substances in a water of known specific gravity: "subtract the specific gravity of pure water from that of the water examined, and multiply the remainder by 1.4. The product is equal to the saline contents in a quantity of the water denoted by the number employed to indicate the specific gravity of distilled water. Thus suppose the specific gravity of the water = 1.079, and that of pure water = 1.000, then 79 × 1.4 = 110.6 = saline contents in 1000 of the mineral water."

This is a useful formula, but open to certain objections; and as it is often of considerable importance to acquire a just knowledge of the proportion of foreign bodies in water, it is advisable to conjoin the above method with the following:

iii. Evaporate a given weight, say 1000 parts, to dryness, and expose the residue for 24 hours, to a temperature not exceeding 300° upon a platinum capsule; weigh it while warm, and the mean obtained from this and the former experiment, will give the proportion of dry saline ingredients within an error of two *per cent.* Thus suppose 1000 parts of the above-mentioned water give by evaporation 114.4 dry residue, then 110.6 + 114.4 = 225 ÷ 2 = 112.5 = quantity of saline matter in a dry state (salts deprived of water of crystallization) existing in the mineral water under investigation.

iv. Having by these preliminary operations ascertained the relative *quantity* of foreign matter in the water under examination, the *nature* of the substances present is next to be inquired into.

1521. The substances which have been found in mineral waters are extremely numerous, but those which ordinarily occur, are the following;

Oxygen.
Nitrogen.
Carbonic acid.
Sulphuretted hydrogen.
Carbonate of lime.
Carbonate of magnesia.
Carbonate of iron.
Muriate of magnesia.
Sea salt.
Sulphate of magnesia.
Sulphate of soda.
Sulphate of lime.

a. Oxygen and nitrogen exist in the greater number of spring waters in the proportions constituting atmospheric air; the proportion of nitrogen is, however, not unfrequently predominant. These gases give no peculiar flavour to the water.

b. Carbonic acid renders mineral waters sparkling and effervescent: it is detected by occasioning a precipitate in aqueous solution of baryta, which dissolves with effervescence in dilute muriatic acid.

c. The presence of sulphuretted hydrogen is known by its peculiar disagreeable smell; by the production of a black precipitate on dropping into the water a solution of nitrate of silver; and by the deposition of sulphur on adding a few drops of nitric acid.

d. The carbonates are dissolved in the water by excess of carbonic acid, and consequently fall upon its expulsion by boiling. Carbonate of lime and magnesia are deposited in the form of a white precipitate. Carbonate of iron occasions the separation of a rusty brown ferruginous powder, and the water is blackened by a few drops of tincture of *galls*.

e. Mr. R. Phillips, in his analysis of Bath waters, has shown that the delicacy of galls, as a test for iron, is curiously affected by the presence of certain salts: if the iron be in the state of protoxide, its detection is facilitated by salts with a base of lime, and by alcalis; if in the state of peroxide, lime prevents the action of the test. This is well shown by dissolving a *very* minute portion of protosulphate of iron in a glass of distilled water, and adding a drop of tincture of galls, which occasions no immediate discoloration; but a drop of lime-water, or other alcali, instantly renders the presence of iron evident; so that the quantity of iron present in a water cannot be correctly judged of by the degree of precipitation occasioned in it by tincture of galls.

f. Ferro-cyanate of potassa is also a good test to show minute quantities of iron in water, by the blue precipitate which it occasions; its action is aided by previously adding two or three drops of nitric acid to the water; but it is an equivocal test compared with galls.

g. The presence of muriatic salts and of chlorides, is indicated by a white cloud on adding sulphate of silver.

h. The sulphates, when present in water, afford a white precipitate on the addition of nitrate of baryta, which is insoluble in nitric acid.

i. Lime is recognised by a white cloud on dropping oxalate of ammonia into the water. A portion of the precipitate collected upon leaf platinum, and heated before the blow-pipe, may be burned into quicklime.

k. Magnesia is rendered evident by adding carbonate of ammonia which throws down the lime, and subsequently pouring in phosphate of soda, which, when magnesia is present, carries a portion of it down in the form of a granular precipitate of ammoniaco-magnesian phosphate.

Such are the readiest means of recognising the presence of the various substances that commonly occur, by the action of re-agents or tests; and, having gained such general information, we next proceed to the analysis of the water, in order to ascertain the relative proportions of the gaseous and saline ingredients which it holds dissolved.

SECTION III. *Analysis of Mineral Waters.*

1522. v. To ascertain the relative proportions of the gaseous contents of water with perfect accuracy, is a very difficult undertaking, and rarely necessary; the following method is sufficiently precise in all ordinary cases of analysis. Provide a Florence flask capable of holding rather more than a measured wine-pint, which quantity of the water under examination is to be introduced into it, and a cork carefully fitted to its neck, through a perforation in which is inserted a glass tube one-eighth inch diameter, rising perpendicularly about 18 inches, and then bent so as to pass conveniently under the shelf of the mercurio-pneumatic apparatus. (Where a sufficiency of mercury cannot be procured, warm water may be substituted, if only carbonic acid be present, and it may be absorbed by transferring the jar containing it to a solution of potassa.) The flask should be placed over an argand lamp, and heat gradually applied till the water fully boils. The gas evolved is to be collected in the usual way, in a graduated jar over quicksilver, and submitted to the following examination:—

vi. Throw up a small quantity of solution of potassa, which, if carbonic acid be present, will absorb it, and the quantity will be shown by the diminution of bulk.

vii. Introduce the remaining air, or a portion of it, into a small bent tube, containing a bit of phosphorus; heat it so as to kindle the phosphorus, and note the diminution of bulk when cold. It is proportional to the oxygen present, and if equal to one-fifth of the whole bulk, the gas may be regarded as atmospheric air*.

viii. If sulphuretted hydrogen be present it may be separated by strong alcoholic solution of iodine, which rapidly absorbs it, and scarcely takes up more than its own volume of carbonic acid gas. Chlorine, added to a mixture of sulphuretted hydrogen and carbonic acid, will also produce the absorption of the former if a little water be present; but it cannot be conveniently used over mercury.

ix. During the ebullition it not unfrequently happens that a precipitation ensues, indicating that the substances thrown down were dissolved by carbonic acid; and in that case they should be separated upon a filter A, after which the remaining water may be evaporated to dryness in a glazed porcelain basin; the dry residue transferred to a silver capsule, and perfectly desiccated at a temperature not exceeding 500°. B.

The precipitate A may consist of carbonate of lime, of carbonate of magnesia, or of oxide of iron; or it may be a mixture of the three; dissolve it in dilute muriatic acid, and add oxalic acid which throws down oxalate of lime; separate this by filtration, and saturate the filtrated portion with carbonate of ammonia, which precipitates the peroxide of iron, and having removed this, evaporate the residuary mixture, and expose the dry salt to a red heat in a small platinum capsule;

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* In separating oxygen a solution of nitric oxide in protosulphate of iron may sometimes conveniently be employed, but it does not give so accurate a result as the action of phosphorus.

the magnesia, if any were present, will remain; if not there will be no residue, for the oxalic acid and muriate of ammonia will be destroyed and volatilized.

100 parts of oxalate of lime indicate 77 of carbonate of lime.

100 parts of red oxide of iron indicate 90 of black oxide, or 143 of carbonate of iron. When carbonic acid holds iron in solution, the metal is in the state of protoxide, and if air be excluded, it requires long boiling to decompose it; for the same reason, if the water be exposed, under the exhausted receiver of the air-pump, it does not readily become brown, as is the case when it is exposed to air; a drop or two of nitric acid facilitates the deposition of the red oxide.

100 parts of pure magnesia are equivalent to 213 of carbonate of magnesia.

x. The dry residue B, is to be digested in six or eight parts boiling alcohol, specific gravity 0.817, which will take up muriate of magnesia, and in some rare cases (where no sulphates are present) muriate of lime. Filter off the alcoholic solution, and wash the residue C with a little fresh alcohol, which add to the former, and evaporate to dryness D. The dry mass D, exposed for some time to a heat of 500°, is generally pure muriate of magnesia; if it contain muriate of lime, the latter earth may be separated by solution of oxalic acid, in the state of oxalate of lime.

I have found it, in some cases, convenient to convert the muriates of lime and magnesia into sulphates, by pouring upon them excess of sulphuric acid, evaporating to dryness, and heating the dry mass red hot. The sulphate of magnesia may then be almost completely separated from the sulphate of lime, by a small quantity of cold water; or a saturated solution of sulphate of lime may be used, which takes up the sulphate of magnesia, and, of course, leaves the sulphate of lime.

The alcohol will also take up a very minute portion of sea-salt, which, however, is too small to require estimation.

xi. The residue C, insoluble in alcohol, may contain sea-salt, sulphate of soda, sulphate of magnesia, and sulphate of lime; digest it in ten parts of boiling distilled water, which, when cold, will have taken up every thing but sulphate of lime, of which an inappreciable portion only will have been dissolved; separate the solution into two equal portions, *a* and *b*.

To *a* add nitrate of silver, and wash and dry the precipitate, which is chloride of silver, and of which 100 parts indicate 41 of sea-salt.

To *b* add acetate of baryta as long as it occasions a precipitate, which is sulphate of baryta, and which is to be separated, dried and weighed. 100 grains are equivalent to 60.5 of sulphate of soda, and to 51 of sulphate of magnesia.

In order to ascertain the quantity of magnesia present, and consequently the quantity of sulphuric acid belonging to it, evaporate the liquid filtered off the barytic precipitate E to dryness; it will contain sea-salt, acetate of soda, acetate of magnesia, and, probably, a portion of the added acetate of baryta; ignite the dry mass, and wash it to separate the sea-salt and soda; magnesia and carbonate of baryta will remain insoluble, upon which pour dilute sulphuric acid; digest, filter, and evaporate the clear liquor to dryness; it is sulphate of magnesia, equivalent of course to the original portion of the salt; deduct the sulphuric acid contained in it from the whole in the precipitate E, and the remainder will give the quantity united to the soda.

xii. To estimate the quantity of sulphate of lime in the water, the
sidue of the evaporation of one point may be washed with cold sa-
rated solution of sulphate of lime, which will dissolve every thing
that sulphate, and which may thus be obtained and weighed; or,
oxalate of ammonia to a given quantity of the boiled and filtered
ter, collect the precipitate, and dry it at a heat of 500°. 100 grains
this oxalate indicate 104 of dry sulphate of lime.

xiii. Such are the general components of mineral waters, and the
ans of ascertaining their relative quantities. Let us suppose the
lowing results have been obtained, with a view to illustrate the mode
drawing up the analysis. By the process v, twelve cubical inches
gas have been expelled during the ebullition of a pint of water.
e exposure to solution of potassa has occasioned a diminution of
ven cubical inches, which, it having been previously ascertained
t no sulphuretted hydrogen was present, may be considered as carbonic
ic acid. The remaining gas thrown up into a tube containing a por-
of phosphorus, and heated, suffers scarcely any diminution, and
phosphorus does not burn: hence it may be regarded as nitrogen.
e gaseous contents, therefore, of the water under examination are
he wine-pint—

Carbonic acid	11 cubic inches,
Nitrogen	1 ditto*.

f sulphuretted hydrogen be present, it is best to have recourse to a
arate operation to estimate its quantity: for this purpose collect
gas as before, and throw up into it a small quantity of alcoholic
tion of iodine. The absorption denotes the quantity of the gas.
i.)

iv. The next step of the operation relates to the examination of
precipitate deposited during ebullition, (ix. A.) Let us suppose
weight of oxalate of lime to be 3 grains, of oxide of iron 1.5
n, and of magnesia 1 grain; then the above data give

	Grains.
Carbonate of lime	2.2
Carbonate of iron	2.4
Carbonate of magnesia	2.1

v. The alcoholic solution (x.) may be diluted with water and test-
y oxalic acid for lime; if absent, evaporate to dryness as directed.
us suppose the residue to be

Muriate of magnesia . . . . 5 grains.

the quantity of muriate of magnesia be considerable, greater ac-
cy is ensured by converting it into sulphate, which is done by
ng it in a capsule of platinum, pouring upon it sulphuric acid, eva-
ing to dryness, and heating the dry mass to dull redness. 100
s of this dry sulphate of magnesia indicate 94 of muriate of mag-
; hence the water under examination would have given 5.35 grains
rains of muriate.

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this nitrogen, a small portion will probably have been derived from the air in the tube
ing the flask with the pneumatic apparatus; a little practice soon enables the operator
tain when it has been expelled; or it may be received entire, and afterwards deducted
whole produce.

If the alcoholic solution contain muriate of lime, that earth must b previously separated by oxalic acid; and 100 parts of oxalate of lim are equivalent to 85 of dry muriate of lime.

xvi. The aqueous solution of the residue (c xi.) being divided int two portions, let us suppose the portion *a* xi. to afford 8.5 of chlorid of silver, which indicates of sea-salt 3.5 grains = 7 grains in the pin

xvii. Let us assume, that the precipitate of sulphate of baryta *b* x weighs 15 grains, indicating of

Sulphuric acid . . . . 5.1 grains.

The process directed in xi. furnishes of

Sulphate of magnesia . . . . 3.75 grains,

which contain 2.5 grains of sulphuric acid, and which deducted fro 5.1 grains leave 2.6 grains, which are adequate to the formation of

Sulphate of soda . . . . . . 4.65 grains.

So that the pint (the water having been divided into two equal portions would contain of

Sulphate of magnesia 3.75×2=7.5 grains.
Sulphate of soda . . 4.65×2=9.3 grains.

xviii. The addition of oxalate of ammonia, or oxalic acid, to a pin of the boiled water (xii.) furnishes a precipitate of 4.7 grains of oxa late of lime, indicating of

Sulphate of lime . . . . 5 grains.

xix. To give a general view, therefore, of the components of the mineral water which has thus been examined, we should place them a follows:—

One wine pint contains

	Cubic Inches.
Carbonic acid	11
Nitrogen	1
Gaseous contents	12

	Grains.
Carbonate of lime	2.20
Carbonate of iron	2.40
Carbonate of magnesia	2.10
Muriate of magnesia	5.00
Sea salt	7.00
Sulphate of magnesia	7.50
Sulphate of soda	9.30
Sulphate of lime	5.
Aggregate weight of solid contents	40.50

xx. Besides the substances now enumerated, and which may be co sidered as the most frequently occurring ingredients in mineral water there are others occasionally present, of which the following is a enumeration, with the best methods of detecting them:

a. Carbonate of soda is known to exist in water, when, after havi been boiled down to half its bulk, and, if necessary, filtered, it redde tumeric paper, and restores the blue of litmus reddened by vinega it also affords an effervescent precipitate with nitrate of baryta, solu in dilute nitric acid. This carbonate is incompatible with the solu salts of lime.

Muriate of lime may also be used to detect the alcaline carbonates,
h which it affords a precipitate of carbonate of lime. Carbonate of
a is distinguished from that of potassa, by the latter affording a pre-
itate in neutral muriate of platinum, which the former does not.
bonate of ammonia is obviously discoverable by its smell, when
d on by caustic fixed alcali or lime.

. Silica is detected by evaporating the water to dryness, and boil-
the residue in dilute muriatic acid. The silica, if present, remains
white powder not altered by a red heat, but instantly fusing with a
icle of carbonate of soda.

. Boracic acid and borax have been found in certain lakes in India,
in some parts of Italy. To detect boracic acid, evaporate to one-
ith the original bulk of the water, and add carbonate of soda as long
occasions any precipitate ; boil and filter. The filtered liquor will
ain borate of soda, with some other salts of the same basis ; eva-
ite to dryness in a platinum crucible, and digest the residue in three
our parts of sulphuric acid, diluted with its bulk of water. If bo-
c acid be present, it will separate in micaceous crystals.

. Alumina has been found in a few mineral waters in the state of a
hate. It may be separated by the following process : Evaporate to
ness, digest in alcohol, and re-dissolve the residue in eight parts of
r ; filter and add oxalic acid, which throws down lime, and which
g separated, leaves magnesia and alumina in solution. Carbonate
mmonia throws down the alumina and leaves the magnesia.
ure ammonia throws down both alumina and magnesia. These
hs may be separated by solution of potassa, which dissolves the
er but not the latter.

Manganese is sometimes found in water, but only in very small
ortion, so as not to amount to more than a trace. Dr. Scudamore
d a trace of manganese in the waters of Tunbridge Wells, and it
never been discovered in larger proportion.

It has been said that certain nitrates are occasionally present in
r, but such solutions can scarcely be called *mineral waters*. If
te of lime be present, it will be taken up from the residue of eva-
tion by alcohol, and may be decomposed by carbonate of potassa,
to afford carbonate of lime and crystals of nitre.

It sometimes happens that water contains lead, which may be de-
d by evaporation to one-eighth its bulk, adding a few drops of ni-
cid, and then hydriodate of potassa, which gives a yellow insolu-
recipitate ; and hydrosulphuret of ammonia, which forms a deep
n or black cloud. These precipitates may be reduced by heating
before the blow-pipe upon charcoal, mixed with a little black flux.

If vegetable or animal matter be contained in water, it gives it a
n colour, especially when evaporated. It may be destroyed in
ry residue by igniting it with a small addition of nitrate of ammo-

e following analyses of mineral waters may be advantageously
lted by the student, as containing a variety of useful details, which
ecessarily omitted in the above observations :—*Analysis of the Hot
gs at Bath*, by Richard Phillips, Esq. *Analysis of the Brighton
beate*, by Dr. Marcet. *Analysis of the Tunbridge Wells Waters*,
. Scudamore. Mr. Children's *Translation of* Thenard's *Essay
emical Analysis*, chap vi.

1523. TABULAR VIEW OF THE COMPOSITION OF MINERAL WATERS.

One Pint (Wine Measure) contains the following ingredients:

	WATERS	GASES			CARBONATES			SULPHATES			MURIATES			Oxide of Iron	Silica	Temperature	Total of Saline Contents	AUTHORITY
		Nitrogen C. I.	Carbonic Acid, C. I.	Sulphuretted Hydrogen C. I.	Carbonate of Soda, grains	Carbonate of Magnesia, grains	Carbonate of Lime, grains	Sulphate of Soda, grains	Sulphate of Magnesia, grains	Sulphate of Lime, grains	Muriate of Soda, grains	Muriate of Magnesia, grains	Muriate of Lime					
CARBONATED	Seltzer	......	17.	......	4.	5.	3.	......	......	......	17.	......	......	....	....	Cold	29.	Bergman.
	Pyrmont	......	26.	......	......	10.	4.5	......	5.5	8.5	1.5	......	......	0.6	....	do.	30.6	Ditto.
	Spa	......	13.	......	1.5	4.5	1.5	......	......	......	0.2	......	......	0.6	....	do.	8.3	Ditto.
	Carlsbad	......	5.	......	5.	......	1.5	8.5	......	......	4.5	......	......	a trace	0.3	165°	19.8	Klaproth.
	Pouges	......	30.	......	10.	1.2	12.	......	......	......	2.2	......	......	2.5	0.5	Cold	28.4	Hassenfratz.
	Saint Parize	......	22.	......	......	0.5	11.5	......	......	13.	......	......	......	....	....	do.	25.	Ditto.
SULPHUREOUS	Harrogate	0.8	1.	2.3	......	0.7	2.5	......	1.3	......	77.	11.	1.5	....	....	do.	94.	Garnet.
	Moffatt	0.5	0.6	1.2	......	......	......	......	......	......	4.5	......	......	.. .	....	do.	4.5	Ditto.
	Aix-la-Chapelle	......	......	5.5	12.	......	4.2	......	......	......	5.	......	......	....	....	143°	21.2	Bergman.
	Cheltenham Sulphur Spring	......	1.5	2.5	......	......	......	23.5	5.	1.2	35.	......	......	0.3	....	Cold	65.	Parkes & Brande.
SALINE	Seidlitz	......	......	......	......	2.5	0.8	......	180.	5.	......	4.5	......	....	....	do.	192.8	Bergman.
	Cheltenham pure Saline	......	......	......	......	......	......	15.	11.	4.5	50.	......	......	....	....	do.	80.5	Parkes & Brande.
	Bristol	......	3.5	......	......	......	1.5	1.5	......	1.5	0.5	1.	......	....	....	74°	6.	Carrick.
	Buxton	0.2	......	......	......	......	1.3	......	......	0.3	0.2	......	......	0.08	....	82°	1.83	Pearson.
	Bath	......	1.2	......	......	......	0.8	1.5	......	9.	3.3	......	......	a trace	0.2	116°	14.6	Phillips.
	Scarborough	......	......	......	......	......	a trace	20.	......	9.	......	......	......	ditto	....	Cold	2.9	Saunders.
	Barege	......	......	uncertain	2.5	......	ditto	......	......	a trace	0.5	......	......	....	....	120	3.	Ditto.
	Plombieres	......	......	......	2.2	......	0.3	2.3	......	......	1.5	......	......	....	0.3	?	66.	Vauquelin.
	Kilburn	......	3.5	8.5 ?	......	0.5	1.	12.	37.	5.5	2.5	5.5	0.2	a trace	....	Cold	64.2	Schmeisser.
	Leamington New Bath	0.4	a trace	a trace	......	......	......	19.	......	14.	58.	1.5	......	0.8	....	do.	88.3	Lambe.
	Leamington Old Bath	0.3	......	ditto	......	......	......	7.5	7.	18.	41.	......	......	....	....	do.	73.5	Ditto.
	Tunbridge	0.50	1.	a trace of oxygen	......	......	0.03	......	......	0.17	0.30	0.03	0.05	0.28	....	do.	0.56	Scudamore.
	Cheltenham Chalybeate	[illegible]	[illegible]	..	0.5	......	......	22.7	6.	2.5	41.3	......	....	0.8	.	do	79.8	Parkes & Brande

TABULAR VIEW of SPECIFIC GRAVITIES and EQUIVALENT NUMBERS of the METALS and their COMBINATIONS.

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
I. POTASSIUM	0.85	40		The following characters belong to the Salts of Potassium: they are all soluble in water, and afford no precipitates with pure or carbonated alcalis; they produce a precipitate in muriate of plantinum, which is a triple compound of potassa, oxide of platinum, and muriatic acid. They are not changed by sulphuretted hydrogen, nor by ferrocyanate of potassa. Added to sulphate of alumina, they enable it to crystallize so as to form octoëdral alum.
—— protoxide, or dry potassa	2.5	48	40 P. + 8 oxygen.	
——— hydrate	1.7	57.	48 Ox. Potassium + 9 water.	
—— peroxide		64	40. P. + 24 oxygen.	
—— chloride		76	40. P. + 36 C.	
—— chlorate		124	48 O. P. + 76 C. A.	
—— oxychlorate		140	48 O. P. + 92 oxych. a.	
—— iodide		165.	40. P. + 125	
—— hydriodate		174	48 O. P. + 126 H. A.	
—— iodate		218	48 O. P. + 165. iod. a.	
—— hydruret		41	40 P. + 1 Hydro.?	
—— hydrogen potassuretted				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
POTASSIUM. nitrate	1.99	102	48 O. P. + 54. N. A.	
——— sulphuret		56.	40 P. + 16 S.	
——— hyposulphite		72	48 O. P. + 24 Hyp. S. A.	
——— sulphite		80	48 O. P. + 32 S. A.	
——— sulphate	2.4	88	48 O. P. + 40 S. A.	
——— bisulphate		128	48 O. P. + 80 S. A.	
——— ammonio-sulphate		145	48 O. P. + 80 S. A. + 17 A.	
——— phosphuret		52	40 P. + 12 Phos.	
——— hypophosphite ?				
——— phosphite		68	48 O. P. + 20 P. A.	
——— phosphate		76	48 O. P. + 28 P. A.	
——— subphosphate		124	96 O. P. + 28 P. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity.	Equivalent Number	COMPOSITION	REMARKS
POTASSIUM. biphosphate		104	48 O. P. + 56 P.A.	
——— carbonate		70	48 O. P. + 22 C. A.	
——— bicarbonate	2.01	92	48 O. P. + 44 C. A.	
——— cyanuret				
——— hydrocyanate				
——— borate		70	48 O. P. + 22 B.A.	
II. SODIUM	0.9	24		All the Salts of Soda are soluble in water; they are not precipitated by pure or carbonated alcalis, nor by hydrosulphuret of ammonia, nor ferrocyanate of potassa; nor do they produce any precipitate in solution of muriate of platinum. They do not convert sulphate of alumina into octoëdral alum.
——— 1. oxide		32	24 S. + 8 O.	
——— hydrated		41	32 O. S. + 9 W.	
——— peroxide		36	24 S. + 12 Ox.	
——— chloride		60	24 S. + 36 C.	
——— chlorate		108	32 O. S. + 76 C. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
SODIUM. oxychlorate		124.	32 O. S.+92 Oxy. C. A.	
—— iodide		149.	24 S.+125	
—— iodate		197.	32 O. S.+165 O. A.	
—— hydriodate		158	32 O. S.+126 H. A.	
—— nitrate	2.09	86	32 O. S.+54 N. A.	
—— sulphuret		40	24 S.+16 Sul.	
—— hyposulphite		56	32 O. S.+24 Hyp. S. A.	
—— sulphite		64.	32 O. S.+32 S. A.	
—— sulphate		72	32 O. S.+40 S. A.	
—— —— crystallized		162	72 S. S.+90 Water	
—— bisulphate		112	32 O. S.+80 S. A.	
—— ammonio sulphate		129	32 O. S.+80 S.A.+17Am.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
SODIUM. phosphuret		36	24 S.+12 P.	
——— phosphite		52	32 O. S.+20 P. A.	
——— phosphate		60	32 O. S.+28 P. A.	
——— biphosphate		88	32 O. S.+56 P. A.	
——— ammonio-phosphate		105	32 O. S.+56 P. A.+17 Am.	
——— carbonate	1.35	54	32 O. S.+22 C. A.	
——— bicarbonate		76.	32 O. S.+44 C. A.	
——— cyanuret				
——— hydrocyanate				
——— borate, or borax	1.74			
III. LITHIUM		9.8?		Lithia is distinguished from potassa and soda, by its high saturating power, by the difficult solubility of its carbonate, by the deliquescency and ready solu-
——— oxide		17.8	9.8 L.+8 O.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
LITHIUM. chloride		45.8	9.8 L+36 C.	bility of its chloride, and by the characters of its sulphate.
—— chlorate		93.8	17.8 O. L.+76. chl. ac.	
—— nitrate		71.8	17.8 O. L.+54. N. A.	
—— sulphate		57.8	17.8 O. L.+40. S. A.	
—— phosphate		45.8	17.8 O. L.+28 P. A.	
—— carbonate		39.8	17.8 O. L.+22. C. A.	
IV. CALCIUM		20		The Salts of Lime furnish precipitates of carbonate of lime by the carbonated alcalis; they afford no precipitate with caustic ammonia. Oxalic acid, and oxalate of ammonia, produce precipitates of oxalate of lime, which, at a red heat, affords quicklime.
—— oxide, or lime	1,5	28	20 C+8 O.	
—— —— hydrate		37	28 O. C.+9 W.	
—— chloride		56	20 C.+36 C.	
—— muriate		65	28 O. C.+37 M. A.	
—— oxymuriate?				

Metals and their Combinations (continued.)

SUBSTANCES.	Specific Gravity	Equivalent Number	COMPOSITION.	REMARKS
CALCIUM. chlorate		104	28 O. C.+76 C. A.	
——— iodide		145	20 C.+125 I	
——— oxyiodate		193	28 O. C.+165 O. A.	
——— hydriodate		154	28 O. C.+126 H. A.	
——— nitrate	1.6	82	28 O. C.+54 N. A.	
——— sulphuret		36	20 C.+16 S.	
——— hyposulphite		52	28 O. C.+24 hyp. S. A.	
——— sulphite		60	28 O. C.+32 S. A.	
——— sulphate		68	28 O. C.+40 S. A.	
——— crystallized		86	68 dry sulphate+18 water	
——— phosphuret		32	20 C.+12 P.	
——— phosphate		56	28 O. C.+28 P. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
LITHIUM. chloride		45.8	9.8 L+36 C.	bility of its chloride, and by the characters of its sulphate.
——— chlorate		93.8	17.8 O. L.+76. chl. ac.	
——— nitrate		71.8	17.8 O. L.+54. N. A.	
——— sulphate		57.8	17.8 O. L.+40. S. A.	
——— phosphate		45.8	17.8 O. L.+28 P. A.	
——— carbonate		39.8	17.8 O. L.+22. C. A.	
IV. CALCIUM		20		The Salts of Lime furnish precipitates of carbonate of lime by the carbonated alcalis; they afford no precipitate with caustic ammonia. Oxalic acid, and oxalate of ammonia, produce precipitates of oxalate of lime, which, at a red heat, affords quicklime.
——— oxide, or lime	1,5	28	20 C+8 O.	
——— ——— hydrate		37	28 O. C.+9 W.	
——— chloride		56	20 C.+36 C.	
——— muriate		65	28 O. C.+37 M. A.	
——— oxymuriate?				

Metals and their Combinations (continued.)

SUBSTANCES.	Specific Gravity	Equivalent Number	COMPOSITION.	REMARKS
CALCIUM. chlorate		104	28 O. C.+76 C. A.	
—— iodide		145	20 C.+125 I	
—— oxyiodate		193	28 O. C.+165 O. A.	
—— hydriodate		154	28 O. C.+126 H. A.	
—— nitrate	1.6	82	28 O. C.+54 N. A.	
—— sulphuret		36	20 C.+16 S.	
—— hyposulphite		52	28 O. C.+24 hyp. S. A.	
—— sulphite		60	28 O. C.+32 S. A.	
—— sulphate		68	28 O. C.+40 S. A.	
—— crystallized		86	68 dry sulphate+18 water	
—— phosphuret		32	20 C.+12 P.	
—— phosphate		56	28 O. C.+28 P. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Numbers	COMPOSITION	REMARKS
CALCIUM. biphosphate		84	28 O. C.+56 P. A.	
——— carbonate	2.7	50	28 O. C.+22 C. A.	
——— borate		50	28 O. C.+22 B. A.	
——— fluoride	3.	36	20 C.+16 Fluorine?	
Hydrofluoric acid		17	16 Fluorine+1 hydrogen	
Fluoboric gas		22	16 F.+6 B.	
	32.68	to hydrogen	23.71 to atmospheric air.	
V. BARIUM		70		The Soluble Barytic Salts furnish white precipitates of carbonate of baryta, by the alcaline carbonates. Sulphuric acid and the soluble sulphates occasion white precipitates of sulphate of baryta in the solutions of the earth. They are poisonous, and tinge flame yellow.
——— oxide (baryta)		78	70 B.+8 O.	
——— hydrate		87	78 O. B.+9 W.	
——— chloride		106	70 B.+36 C.	
——— chlorate		154	78 O. B.+76 C. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
BARIUM. iodide		195	70 B. + 125 I.	
——— iodate		243	78 O. B. + 165 I. A.	
——— hydriodate		204	78 O. B. + 126 H. A.	
——— nitrate		132	78 O. B. + 54 N. A.	
——— sulphuret		86	70 B. + 16S.	
——— hyposulphite		102	78 O. B. + 24 hyp. S. A.	
——— sulphite		110	78 O. B. + 32 S. A.	
——— sulphate	4.4	118	78 O. B. + 40 S. A.	
——— phosphuret		82	70 B. + 12 P.	
——— phosphite		98	78 O. B. + 20 P. A.	
——— phosphate	1.28	106	78 O. B. + 28 P. A.	
——— carbonate	4.2	100	78 O. B. + 22 C. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
BARIUM. borate		100	78 O. B. + 22 B. A.	
VI. STRONTIUM		44		The Salts of Strontium furnish white precipitates with the alcaline carbonates, and with sulphuric acid and sulphates; they tinge flame of a fine red; they are not poisonous. They are decomposed by baryta, which has a stronger attraction for acids than strontia; they are more soluble than barytic salts, but pure strontia is less soluble than baryta.
——— oxide		52	44 S. + 8 O.	
——— hydrate		61	52 O. S. + 9 W.	
——— chloride		80	44 S. + 36 C.	
——— chlorate		128	52 O. S. + 76 C. A.	
——— muriate		89	52 O. S. + 37 M. A.	
——— iodide		169	44 S. + 125 I.	
——— iodate		217	52 O. S. + 165. I. A.	
——— nitrate		106	52 O. S. + 54 N. A.	
——— sulphuret		60	44 S. + 16 Sul.	
——— hyposulphite		76	52 O. S. + 24 Hyp. S. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity.	Equivalent Number	COMPOSITION	REMARKS
STRONTIUM. sulphite		84	52 O. S. + 32 S.A.	
——— sulphate	3.9	92	52 O. S. + 40 S. A.	
——— phosphate		80	52 O. S. + 28 P. A.	
——— carbonate	3.6	74	52 O. S. + 22 C. A.	
——— borate		74	52 O. S. + 22 B. A.	
VI. MAGNESIUM		12		The salts of magnesia are decomposed by solution of potassa, and by its carbonate; the precipitate does not re-dissolve in excess of the alcalis, but readily dissolves in excess of sulphuric acid. The salts of magnesia are not precipitated by a solution of bicarbonate of potassa (cold), nor by carbonate of ammonia; but if heat be applied, carbonic acid escapes, and the earth is precipitated in the state of carbonate. The salts of magnesia are only partially decomposed
——— oxide	2.3	20	12 M. + 8 O.	
——— ——— hydrate		29	20 O. M. + 9 W.	
——— chloride		48	12 M. + 36 C.	
——— muriate.		57	20 O. M. + 37 M. A.	
——— chlorate		96	20 O. M. + 76 C. A.	
——— hydriodate		146	20 O. M. + 126 H. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
MAGNESIUM. nitrate		74	20 O. M. + 54. N. A.	by ammonia, which forms triple salts with the earth and acid. Oxalate of ammonia does not precipitate magnesia.
——— ammonio-nitrate		145	20 O. M. + 108 N. A. + 17 Am.	
——— sulphuret				
——— hyposulphite		44	20 O. .M + 24 Hypo. S. A.	
——— sulphite		52	20 O. M. + 32 S. A.	
——— sulphate	1.66	60	20 O. M. + 40 S. A.	
——— ——— crystallized		123	60 S. M. + 63 water	
——— ammonio-sulphate		117	20 O. M. + 80 S. A. + 17 amm.	
——— potassa-sulphate		149	20 O. M. + 80 S. A. + 48 potassa	
——— phosphate		48	20 O. M. + 28 P. A.	
——— bi-phosphate		76	20 O. M. + 56 P. A.	
——— ammonio-phosphate		93	20 O. M. + 56 P. A. + 17 amm.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
MAGNESIUM. carbonate		42	20 O. M.+22 C. A.	
——— bicarbonate		64	20 O. M.+44 C. A.	
——— borate		42	20 O. M.+22 B. A.	
VIII. MANGANESE	6.85	28		The Salts of Manganese are not precipitated by hydriodic acid. They furnish white precipitates with the alcalis, which blacken by exposure to air. They are precipitated white by ferrocyanate of potassa, and yellow by hydrosulphuret of ammonia.
——— 1. oxide		36	28 M.+8 O.	
——— 2. oxide		40	28 M.+12 O.	
——— peroxide		44	28 M.+16 O.	
——— chloride		64	28 M.+36 C.	
——— nitrate		90	36 O. M.+54 N. A.	
——— sulphuret				
——— hyposulphite		60	36 O. M.+24 hyp. S. A.	
——— sulphate		76	36 O. M.+40 S. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
MANGANESE. red sulphate?	....			
——— phosphuret	....	40	28 M.+12 P.	
——— phosphate.	....	64	36 O. M.+28 P. A.	
——— carbonate	....	58	36 O. M.+22 C. A.	
IX. IRON	7.78	28		The Solutions of Iron are known by affording a purple or black precipitate to infusion of galls, which is an extremely delicate test of the presence of the metal, provided any earthy or alcaline salt be present. They give no precipitate with hydriodic acid.
—— 1. oxide	....	36	28 I. +8 O.	
—— 2. oxide	....	40	28 I.+12. O.	
—— 1. chloride	....	64	28 I+36 C.	
—— 2. chloride	....	82	28 I.+54 C.	
—— protomuriate	....	73	36 O. I.+37 M. A.	
—— permuriate	....	95.5	40 O. I.+55.5 M. A.	
—— chlorate				

Metals and their Combinations (continued.)

SUBSTANCES.	Specific Gravity	Equivalent Number	COMPOSITION.	REMARKS
Iron. iodide		153	28 I.+125 Iod.	The pure salts containing the black oxide give a white or very pale blue precipitate with ferrocyanate of potassa; while those containing the brown oxide furnish a dark blue precipitate, (Prussian blue.)
—— protonitrate		90	36 O. I.+54 N. A.	
—— pernitrate		121	40 O. I.+81 N. A.	
—— sulphuret		44	28 I.+16 S.	
—— bisulphuret		60	28 I.+32 S.	
—— hyposulphite?				
—— protosulphate		76	36 O. I.+40 S. A.	
———— crystallized	1.83	139	76 dry+63W. (7 props.)	
—— persulphate?				
—— hydrosulphuret				
—— phosphuret		40	28 I.+12 P.	
—— protophosphate		64	36 O. I.+28 P. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Iron. perphosphate?				
—— carburet				
—— carbonate		58	36 O. I. + 22 C. A.	
X. Zinc	7	34		The Solutions of Zinc are not precipitated by hydriodic acid. Potassa, soda, and ammonia, form white precipitates redissoluble in excess either of acid or alcali. Hydrosulphuret of ammonia produces a yellowish white precipitate; and the soluble phosphates, borates, and carbonates, all form white precipitates.
—— oxide		42	34 Z. + 8 O.	
—— chloride		70	34 Z. + 36 C.	
—— chlorate		118	42 O. Z. + 76 C. A.	
—— muriate		79	42 O. Z. + 37 M. A.	
—— iodide		159	34 Z. + 125 I.	
—— iodate		207	42 O. Z. + 165 I. A.	
—— hydriodate		168	42 O. Z. + 126 H. A.	
—— nitrate		96	42 O. Z. + 54 N. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Zinc. sulphuret		50	34 Z. + 16 S.	
—— hyposulphite		66	42 O. Z. + 24 Hyp. S. A.	
—— sulphite		74	42 O. Z. + 32 S. A.	
—— sulphate	1.9	82	42 O. Z. + 40 S. A.	
———— crystallized		145	82 Z. + 63 Water (9×7)	
—— hydrosulphuret				
—— phosphuret		46	34 Z. + 12 P.	
—— phosphate		70	42 O. Z. + 28 P. A.	
—— carbonate		64	42 O. Z. + 22 C. A.	
—— borate		64	42 O. Z. + 22 B. A.	
XI. Tin	7.20	59?		The Hydriodic Acid affords a fine orange precipitate with solution of muriates of tin, provided there be no
—— 1. oxide		67	59 T. + 8 O.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
TIN. 2. oxide		75	59 T. + 16 O.	excess of acid. Hydrosulphuret of ammonia produces a precipitate of a deep orange colour.
—— 1. chloride		95	59 T. + 36 O.	
—— 2. chloride		131	59 T. + 72 C.	
—— protomuriate		104	67 O. T. + 37 M. A.	
—— permuriate		149	75 O. T. + 74 M. A.	
—— iodide		184	59 T. + 125 I.	
—— nitrate		121	67 O. T. + 54 N. A.	
—— sulphuret		75	59 T. + 16. S.	
—— bisulphuret		91	59 T. + 32 S.	
—— sulphate		107	67 O. T. + 40 S. A.	
—— hydrosulphuret				
—— phosphuret		71	59 T. + 12 P.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity.	Equivalent Number	COMPOSITION	REMARKS
XII. CADMIUM	8.63	55.8 ?		Cadmium is readily soluble in muriatic acid. Its neutral solutions are precipitated yellow by sulphuretted hydrogen, and furnish a metallic precipitate upon immersed zinc. The annexed equivalent of Cadmium is deduced from Stromeyer's Analyses (1419.)
—— oxide		63.8	55.8 C. + 8. O.	
—— chloride		91.8	55.8 C. + 36. Chlor.	
—— iodide		180.5	55.8 + 125. Iod.	
—— nitrate		117.8	63.8 O. C. + 54. N. A.	
—— sulphuret		71.8	55.8 C. + 16 S.	
—— sulphate		103.8	63.8 O. C. + 40. S. A.	
—— phosphuret		67.8	55.8 C. + 12 P.	
—— phosphate		91.8	63.8 O. C. + 28 P. A.	
—— carbonate		85.8	63.8 O. C. + 22. C. A.	
XIII. COPPER	8.8	64		The salts of this metal containing the peroxide, are distinguished by their blue and green colours; their solu-
—— 1. oxide		72	64 C. + 8 O.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Copper. 2. oxide		80	64 C. + 16. O.	tions afford blue precipitates of hydrated oxide with the alcalis, and these redissolve in excess of ammonia, producing a deep blue solution. A plate of iron precipitates metallic copper; ferrocyanate of potassa affords a fine brown precipitate; hydrosulphuret of ammonia, one of a dirty brown; hydriodic acid produces an insoluble iodide of an ash grey colour. The salts of copper containing the protoxide have hitherto been but imperfectly described.
—— 1. chloride		100	64 C. + 36 C.	
—— 2. chloride		136	64 C. + 72 C.	
—— chlorate				
—— iodide		189	64 C. + 125 I.	
—— sub-permuriate?		117	80 O. C. + 37 M. A.	
—— permuriate		154	80 O. C. + 74 M. A.	
—— nitrate	2.17	188	80 O. C. + 108 N. A.	
—— ammoniuret				
—— sulphuret		80	64 C. + 16 S.	
—— bisulphuret		96	64 C. + 32 S.	
—— per-hyposulphite		104	80 O. C. + 24 Hyp. S. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
COPPER. persulphite		112	80 O. C.+32 S. A.	
——— potassa persulphite		192	80 O. C.+64 S. A.+48 pot.	
——— persulphate (dry)		160	80 O. C.+80 S. A.	
——— persulphate crystallized	2.19	250	80 O. C.+80 S. A.+90 water.	
——— subpersulphate				
——— hydrosulphuret				
——— phosphuret		76	64 C.+12 P.	
——— protophosphate		100	72 O. C.+28 P. A.	
——— perphosphate		136	80 O. C.+56 P. A.	
——— percarbonate		102	80 O. C.+22 C. A.	
——— perborate		102	80 O. C.+22 B. A.	
XIV. LEAD	11.35	104		

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
LEAD. 1. oxide		112	104 L. + 8 O.	The soluble Salts of Lead furnish colourless solutions of a sweetish taste, precipitated white by sulphate and ferrocyanate of potassa, and by infusion of galls; brownish black by sulphuretted hydrogen; and brown by hydrosulphuret of ammonia. Hydriodic acid affords a fine yellow precipitate of iodide of lead. The alcalis produce white precipitates, *easily soluble* in excess of potassa or soda, but *insoluble* in excess of ammonia. Zinc precipitates metallic lead. The insoluble salts of lead treated by the blow-pipe on charcoal, afford a globule of lead.
—— 2. oxide		116	104 L. + 12 O.	
—— 3. oxide		120	104 L. + 16 O.	
—— chloride		140	104 L. + 36 C.	
—— chlorate		188	112 O. L. + 76 C. A.	
—— iodide		229	104 L. + 125 I.	
—— iodate		277	112 O. L. + 165 I. A.	
—— nitrate		166	112 O. L. + 54 N. A.	
—— subnitrate		278	224 O. L. + 54 N. A.	
—— sulphuret		120	104 L. + 16 S.	
—— sulphite		144	112 O. L. + 32 S. A.	
—— sulphate		152	112 O. L. + 40 S. A.	

Metals and their Combinations (continued.)

SUBSTANCES.	Specific Gravity	Equivalent Number	COMPOSITION.	REMARKS
LEAD, hydrosulphuret				
—— phosphuret		116	104 L. + 12 P.	
—— phosphite		132	112 O. L. + 20 Ps. A.	
—— phosphate		140	112 O. L. + 28 P. A.	
—— carbonate		134	112 O. L. + 22 C. A.	
XV. ANTIMONY	6.70	48 ?		
——— 1. oxide		56	48 A. + 8 O.	The protomuriate of antimony is precipitated white by water; the precipitate is a subsalt. Sulphuretted hydrogen, and hydrosulphuret of ammonia, give an orange precipitate, and a plate of iron or zinc throw down the metal in the form of a blac powder.
——— 2. oxide		64	48 A. + 16 O.	
——— chloride		84	48 A. + 36 C.	
——— iodide		173	48 A. + 125 I.	
——— muriate				
——— sulphuret		64	48 A. + 16 S.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
ANTIMONY. protosulphate		96	56 O. A.+40 S. A.	
——— hydrosulphuret				
——— phosphuret		60	48 A.+12 P.	
——— phosphate		84	56 O. A.+28 P. A.	
XVI. BISMUTH	9.80	72		The Salts of Bismuth are precipitated white by water—brownish black by sulphuretted hydrogen—yellowish white by ferrocyanate of potassa, and hydriodic acid affords a deep brown iodide of bismuth.
——— oxide		80	72 B.+8 O.	
——— chloride		100	72 B.+36 C.	
——— iodide		197	72 B.+125 I.	
——— nitrate		134	80 O. B.+54 N. A.	
——— sulphuret		88	72 B.+16 S.	
——— sulphate		120	88 O. B.+40 S. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
COBALT	8	32.5?		Nearly all the Salts of Cobalt are of a red colour, when in dilute solution, but green or blue when concentrated: potassa, soda, and ammonia produce in them blue precipitates of hydrated oxide, which is soluble in excess of ammonia, producing a red solution. Hydrosulphuret of ammonia gives a black precipitate: Ferrocyanate of potassa a pale green. Carbonates, phosphates, and arseniates, produce red precipitates. Hydriodic acid does not precipitate the salts of cobalt.
—— 1. oxide		40.5	32.5 C. + 8 O.	
—— 2. oxide		44.5	32.5 C. + 12 O.	
—— chloride		68.5	32.5 C. + 36 C.	
—— muriate		77.5	40.5 O. C. + 37 M. A.	
—— sulphuret		48.5	32.5 C. + 16 S.	
—— sulphate		80.5	40.5 O. C. + 40 S. A.	
—— sulphate crystallized		143.5	40.5 O. C. + 40 S. A. 63 Water.	
—— phosphuret		44.5	32.5 C. + 12 P.	
—— phosphate		68.5	40.5 O. C. + 28 P. A.	
—— carbonate		62.5	40.5 O. C. + 22 C. A.	
XVIII. URANIUM	9	64?		

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Arseniate of ammonia		88	71 A. A. + 17 A.	The Arseniate of Potassa produces a reddish precipitate in nitrate of silver; straw-coloured with nitrate, and yellow with pernitrate of mercury; white with nitrate of lead; pale green with nitrate of nickel; pale blue with nitrate of copper; pink with nitrate of cobalt; white with protomuriate of tin; no precipitate with permuriate of tin; pale sea-green with muriate and permuriate of iron; straw colour with nitrate of uranium; and white with sulphate of zinc.
——— potassa		119	71 A. A. + 48 P.	
Binarseniate of potassa		190	142 A. A. + 48 P.	
Arseniate of soda		103	71 A. A. + 32 O. S.	
——— lime		99	71 A. A. + 28 Lime.	
——— baryta		149	71 A. A. + 78 O. B.	
——— strontia		123	71 A. A. + 52 S.	
——— magnesia		91	71 A. A. + 20 M.	The compounds of the arsenic and arsenious acids are decomposed when heated with charcoal, and exhale an alliaceous smell.
——— manganese		107	71 A. A. + 36 O. M.	
Protarseniate of iron		107	71 A. A. + 36 O. I.	
Perarseniate of iron		146.5	106.5 A. A. + 40 O. I.	
Arseniate of zinc		113	71 A. A. + 42 O. Z.	
——— tin		138	71 A. A. + 67 O. T.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Protarseniate of copper		143	71 A. A. + 72 O. C.	
Perarseniate o c opper		220	142 A. A. + 80 O. C.	
Arseniate of lead		183	71 A. A. + 112 O. L.	
——— bismuth		151	71 A. A. + 80 O. B.	
——— cobalt		111.5	71 A. A. + 40.5 O. C.	
——— uranium?				
XXIV. Molybdenum	7.40	47?		
——— 1. oxide		55	47 M. + 8 O.	
——— 2. oxide		63	47 M. + 16 O.	
——— 3. oxide (acid)		71	47 M. + 24 O.	
——— sulphuret		79	47 M. + 32 S.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Molybdate of ammonia	....	88	71 M. A. + 17 A.	
—— potassa	....	119	71 M. A. + 48 P.	
—— soda	....	103	71 M. A. + 32 S.	
—— lead	....	183	71 M. A. + 112 O. L.	
XXV. CHROMIUM	5.9	30.9?		
—— 1. oxide	....	38.9	30.9 C. + 8 O.	Chromic Acid and Chromate of Soda produce insoluble precipitates in solutions of silver, mercury, lead, copper, iron, and uranium; the colours are crimson, red, yellow or orange, apple-green, brown, and yellow. No precipitate is formed in solutions of nickel, zinc, tin, cobalt, gold, or platinum.
—— 2. oxide (chromic acid)	....	46.9	30.9 C. + 16 O.	
Chromate of ammonia	....	63.9	46.9 C. A. + 17 A.	
—— potassa	....	94.9	46.9 C. A. + 48 P.	
—— lime	....	74.9	46.9 C. A. + 28 L.	
—— baryta	....	124.9	46.9 C. A. + 78 B.	
—— iron	....	82.9	46.9 C. A. + 36 O. I.	

Metals and their Combinations (continued.)

SUBSTANCES.	Specific Gravity	Equivalent Number	COMPOSITION.	REMARKS
Chromate of lead		158.9	46.9 C. A. + 112 O. L.	
XXVI. Tungsten	17.5	96		
——— Tungstic acid		120	96 T. + 24 O.	
Tungstate of lime		148	120 T. A. + 28 L.	
——— manganese		156	120 T. A. + 36 O. M.	
XXVII. Columbium.		145.8?		
——— oxide (acid)		153.8	145.8 C. + 8 O.	
Columbate of potassa		201.8	153.8 C. A. + 48 P.	
XXVIII. Nickel	8.5	29.63?		The Salts of Nickel form green solutions, of a sweetish acrid flavour; ammonia gives green precipitates, redissoluble in excess of alcali, and forming triple salts. Ferrocyanate of potassa forms
——— oxide		37.63	29.63 N. + 8 O.	
——— hydrate		46.63	37.63 O. N. + 9 W.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
NICKEL. chloride	....	65.63	29.63 N.+36 C.	a greenish precipitate; hydrosulphuret of ammonia gives a black precipitate; hydriodic acid forms a pea-green iodide.
——— iodide	....	154.63	29.63 N.+125 I.	
——— nitrate	....	91.63	37.63 O. N.+54 N. A.	
——— ammoniuret				
——— sulphuret	....	45.63	29.63 N.+16 S.	
——— sulphate (dry)	....	77.63	37.63 O. N.+40 S. A.	
——— crystallized	....	140.63	77.63 S. N.+63 W.	
——— potassa-sulphate	....	165.63	37.63 O. N.+80 S.A.+48 P.	
——— ferro-sulphate	....	153.63	37.63 O, N.+80 S. A.+36 O. I.	
——— phosphuret	....	41.63	29.63 N.+12 P.	
——— phosphate	....	65.63	37.63 O. N.+28 P. A.	
——— carbonate	....	59.63	37.63 O. N.+22 C. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Nickel. borate			37.63 O. N. + B. A.	
—— ammonio-sulphate		134.63	37.63 O. N. + 80 S. A. + 17 amm.	
XXIX. Mercury	13.50	200		
—— protoxide		208	200 M. + 8 O.	The Mercurial Salts are volatilized by heat. They are precipitated yellowish by ferrocyanate of potassa; deep brown by hydrosulphuret of ammonia; and copper separates pure mercury. The salts with the protoxide, give black precipitates with the alcalis, and white with muriatic acid. The salts with the peroxide furnish to the fixed alcalis reddish precipitates, and white with ammonia.
—— peroxide		216	200 M. + 16 O.	
—— chloride		236	200 M. + 36 C.	
—— bichloride		272	200 M. + 72 C.	
—— muriate?				
—— chlorate	Chlorate of Mercury is yellow and insoluble. Perchlorate furnishes crystals.			
—— iodide		325	200 M. + 125 I.	Hydriodic Acid gives a yellow precipitate in solutions of protoxide, and a red precipitate with the peroxide. These are the protiodide and periodide of mercury.
—— periodide		450	200 M. + 250 I.	
—— hydriodate		334	208 O. M. + 126 H. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Mercury. protonitrate		262	208 O. M. + 54 N. A.	Phosphoric Acid produces a white insoluble precipitate in nitrate of mercury, but no precipitate in the pernitrate.
——— pernitrate		324	216 O. M. + 108 N. A.	
——— subpernitrate		486	432 O. M. + 54 N. A.	
——— sulphuret		216	200 M. + 16 S.	
——— bisulphuret		232	200 M. + 32 S.	
——— sulphite?		240	208 O. M. + 32 S. A.	
——— protosulphate		248	208 O. M. + 40 S. A.	
——— persulphate		296	216 O. M. + 60 S. A.	
——— bipersulphate?				
——— subpersulphate		256	216 O. M. + 40 S. A.	
——— hydrosulphuret?				
——— phosphuret?				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity.	Equivalent Number	COMPOSITION	REMARKS
MERCURY. protophosphate		236	208 O. M. + 28 P. A.	
——— perphosphate		272	216 O. M. + 56 P. A.	
——— protocarbonate		230	208 O. M. + 22 C. A.	
——— percarbonate		260	216 O. M. + 44 C. A.	
——— cyanuret		252	200 M. + 52 C.	
——— protoborate		230	208 O. M. + 22 B. A.	
——— perborate		260	216 O. M. + 44 B. A.	
——— protoarseniate		279	208 O. M. + 71 A. A.	
——— perarseniate		358	216 O. M. + 142 A. A.	
——— chromate?				
——— tungstate?				
XXX. OSMIUM.				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
XXXI. Iridium	18			
XXXII. Rhodium	106			
XXXIII. Palladium	11			
XXXIV. Silver	10.50	109.3?		The salts of silver are reduced upon charcoal by the blow-pipe. The soluble salts are precipitated by the alcalis, which furnish dark olive precipitates; by sulphuretted hydrogen and hydrosulphuret of ammonia, nearly black; by infusion of galls, yellow brown; by ferrocyanate of potassa, white. Muriatic acid, and the muriates, give white precipitates of chloride of silver. Sulphate of iron, and a plate of copper, throw down metallic silver.
—— oxide		117.3	109.3 S. + 8 ox.	
—— chloride		145.3	109.3 S. + 36 C.	
—— chlorate	A detonating salt.			
—— iodide —— hydriodate	Hydriodic acid throws down iodide of silver from the nitrate, at first white, but becoming *very* soon yellow, then grey and blackish.			
—— nitrate		171.3	117.3 O. S. + 54 N. A.	
—— ammoniuret	Liquid ammonia easily dissolves the oxide of silver. When the solution is evaporated, a grey compound remains, which leaves metallic silver when heated. Sometimes it detonates.			

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
SILVER. sulphuret		125.3	109.3 S. +16 Sul.	
—— sulphite	forms a white and difficultly soluble salt.			
—— sulphate		157.3	117.3 O. S.+40 S. A.	
—— hydrosulphuret				
—— phosphuret		121.3	109.3 S.+12 P.	
—— phosphate		145.3	117.3 O. S.+28 P. A.	
—— carbonate		139.3	117.3 O. S.+22 C. A.	
—— cyanuret		161.3	109.3 O. S.+52 C.	
—— hydrocyanate				
—— borate	Boracic acid produces no precipitate in solutions of silver, but borate of soda throws down a white *borate of silver*.			
Arseniate of Silver		188.3	117.3 O. S.+71 A. A.	
Molybdate ——		188.3	117.3 O. S.+71 M. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
SILVER. Chromate		164.2	117.3 O. S.+46.9 C. A.	
—— Tungstate		237.3	117.3 O. S.+120 T. A.	
XXXV. GOLD.	19.30	103.4?		
—— peroxide		111.4	103.4 G.+8 ox.	The salts of gold are yellow and soluble in water. Potassa and soda produce in them yellow precipitates. Sulphuretted hydrogen and hydrosulphuret of ammonia occasion black precipitates: phosphuretted hydrogen, a purple precipitate: a plate of tin or muriate of tin, a purple powder. Sulphate of iron separates minutely-divided metallic gold. Tincture of galls gives a brown precipitate. Ferrocyanate of potassa occasions no precipitate.
—— chloride		139.4	103.4 G.+36 C.	
—— muriate		148.4	111.4 ox. G.+37. M. A.	
—— chlorate				
—— iodide —— hydriodate	Hydriodic acid produces an insoluble yellow precipitate in dilute muriate of gold, which is the iodide of gold. Heat separates the iodine.			
—— nitrate		165.4?	111.4 ox. G.+54 N. A.	
—— sulphuret		135.4?	103.4 G.+32 S.	
—— sulphite	Sulphurous acid produces a metallic precipitate in solution of gold.			

Metals and their Combinations (continued.)

SUBSTANCES.	Specific Gravity	Equivalent Number	COMPOSITION.	REMARKS
GOLD. sulphate				
—— phosphuret		115.4	103.4 G + 12 P.	
—— phosphite	Neither these acids, nor their neutral salts, occasion any precipitate in solution of muriate of gold.			
—— phosphate				
—— carbonate				
—— cyanuret				
XXXVI. PLATINUM				The solutions of these salts are deep or brownish yellow. They afford no precipitate with solutions of soda, of sulphate of iron, or of Ferrocyanate of potassa. The addition of the latter produces a fine green solution. Potassa and ammonia, and many of their salts, occasion yellow precipitates. Sulphuretted hydrogen occasions a black precipitate. Infusion
—— protoxide				
—— peroxide				
—— chloride				
—— muriate				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
PLATINUM. iodide	Hydriodic acid precipitates a dingy brown iodide of platinum, decomposed by heat.			of galls gives a dingy brown precipitate.
——— hydriodate				
——— nitrate				The analysis of these compounds are, at present, too much at variance to enable us, with sufficient precision to ascertain the representative number of Platinum.
——— ammoniuret				
——— ammonio-muriate				
——— sulphuret				
——— sulphate				
——— hydrosulphuret	Hydrosulphuret of ammonia produces a brown precipitate in muriate of platinum. This is probably a sulphuretted hydrosulphuret.			
——— phosphuret				
——— phosphate	A soluble salt, obtained by dissolving oxide of platinum in phosphoric acid.			
XXXVII. SILICIUM	....	16		

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
Silica	2.6	32	16 S. + 16 O.	Of the following bodies such combinations only are here set down as have been examined with sufficient precision. Their distinctive characters are given at length in the text.
Silicated fluoric acid	3.574	=sp. gr. to	atmospheric air.	
———	49.2	=sp. gr. to	hydrogen.	
———	110,78	grs. = weight	of 100 C. I.	
XXXVIII. ALUMIUM		17.6		
Alumina		25.6	17.6 A. + 8 O.	
——— sulphate		65.6	25.6 O. A. + 40 S. A.	
Alum (dry)		259.2	131.2 S. A. + 128 Bisul. Pot.	
—— (crystallized)		457.2	259.2 dry + 198 Water (22 props.)	
XXXIX. ZIRCONIUM		37?		
Zirconia		45	37 Z. + 8 O.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Equivalent Number	COMPOSITION	REMARKS
XL. Glucinum	....	21.3?		
Glucina	2.97	29.3	21.3 G. + 8 O.	
XLI. Yttrium	....	32		
Yttria	....	40	32 Y. + 8 O.	
XLII. Thorinum				

CHAPTER VIII.

OF VEGETABLE SUBSTANCES.

1523. HAVING in the preceding chapters considered the properties of the elementary substances, and such of their compounds as can be artificially formed, or are found in the mineral world, we proceed in this and in the succeeding chapter to examine the states of combination in which they occur in organic substances.

Objects of this chapter.

The several sections of the present chapter will relate to the formation of vegetable substances and their chemical physiology; to the analysis of vegetable products, and the properties of their proximate component parts; and to the phænomena and products of fermentation.

SECTION I. *Of the Structure and Growth of Plants, and of the chemical Phænomena of Vegetation.*

Organs of plants.

1524. In examining the external structure of a perfect and full-grown vegetable, or plant, the essential organs of which it is observed to consist are the root, the stem, the leaves, the flowers, and the seeds.

Root.

Stem.

Leaves.

The *root* serves to attach the plant to the soil, and is one of its organs of nutriment; in its structure it closely resembles the stem, of which it may be regarded as a continuation, terminating in more or less minute ramifications, analogous to the branches deprived of leaves. The *stem* is usually erect and subdivided into *branches* which bear the *leaves* and *flowers*, and upon which the *seeds* are ultimately produced.

Cortex wood, medulla.

1525. When a branch of a tree is cut transversely it exhibits a *cortical portion*, or *bark*; *wood*; and *pith*, or *central medullary substance*.

Cellular substance.

The bark is subdivisible into an external layer or *cuticle*, under which is a *cellular substance* lying upon the innermost part, or *cortical layers*.

Cuticle.

1526. The *cuticle* extends over every part of the plant; it allows of absorption and transpiration, and being generally transparent, at least upon the leaves and flowers, it admits the influence of light. The cuticle varies in texture and appearance in different plants. On the currant and elder tree it is smooth and scales off: on the fruit of the peach, and on the leaf of the mullein, it is covered with wool; on the leaf of the white willow, it is silky; in several plants, it is covered with hair and bristles, which in the nettle are perforated and contain a venomous fluid: on the plum and upon many leaves, it is varnished with a resinous exudation, which prevents injury from rain: it is fungous on the bark of the cork tree: and on grasses, on the equisetum, and especially on different species of the rattan, it is covered with a glassy network of siliceous earth.

Silica is also found in the hollow stem of the bamboo, constituting the substance called *tabasheer*, the optical properties of which are peculiar, and have been described by Dr. Brewster.—*Phil. Trans.* 1819.

Parenchyma.

1527. Under the cuticle, or epidermis, is the *parenchyma*; a soft substance, appearing under the microscope of a honeycombed or hexagonal cellular structure, resulting from the mechanical laws which influence the pressure of soft cylinders.

Cortical layers.

1528. The *cortical layers* appear of a tubular and fibrous texture, and with the cellular substance receive and elaborate the sap. In the older branches and trunks of trees, the bark consists of as many layers as they are years old; the innermost layer has been called the *liber*, in which the most essential vital functions of the plant appear to go on, and by which a new layer of wood is annually secreted.

Sap-wood. Heart-wood.

1529. The *wood* consists of an outer stratum of living wood called the *alburnum*, or *sap-wood*; and an inner dead part, or *heart-wood*. In the alburnum, which is tubular, the sap appears to rise from the roots; it passes into the leaves, where it undergoes changes, and thence enters the vessels of the inner bark, in which new parts are produced, and which is thus enabled to generate new wood.

Spurious and silver grain.

When the tubular structure is examined by a magnifier, it appears composed of vessels, some of which are simple, others perforated in various ways, and others spiral. The fibres of the wood consist of concentric and diverging layers, which have been called the *spurious* and the *silver grain*.

Pith.

1530. The *pith* occupies the centre of the wood; it is very variable in quantity in plants of different ages, and appears not to be of essential importance. It probably sometimes serves as a reservoir of moisture.

Leaves.

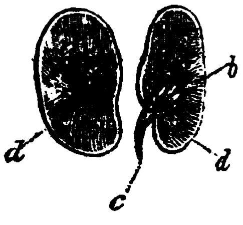
1531. The *leaves* are highly vascular, and appear composed of a woody skeleton, supporting a tubular and cellular structure. They allow of evaporation and absorption, and in them the sap is concocted and rendered fit for the production of new parts. The absorption and evaporation principally take place upon the lower surface of the leaf. In most plants the leaves are annually re-produced.

Flower of calyx, corolla, pistil, stamen, style, anthers, pollen.

1532. The *flower* consists of the *calyx*, or green support of the *corolla*, or *floral leaves*; and of the *pistil* and *stamens*. The pistil is surmounted by the *style*, and is connected with a vessel containing the rudiments of the seeds. The stamens are surmounted by *anthers*, covered with a fine powder called the *pollen*, and which, being deposited upon the style, renders the seeds productive.

Seed, cotyledon, plume, radicle.

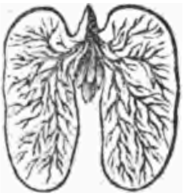
1533. The *seed* is extremely various in form. It consists essentially of the *cotyledon*, the *plume*, and the *radicle*. The cotyledon contains the matter necessary for the early nutrition of the young plant. Sometimes it is single sometimes double, and sometimes divisable into several lobes. The plume afterwards produces the stem and leaves, and is enveloped by the cotyledons; the radicle generally projects a little, and when the seed vegetates it becomes the root. These parts are usually enveloped in a common membrane, and are well seen in the garden bean, represented in the annexed cut. *aa* are the cotyledons; *b* the plumula; *c* the radicle; *d d* the external membrane.



1534. When a seed is placed under favourable circumstances the different parts begin to grow; the membranes burst, the plumula gra-

Germination.

dually expands and rises to the surface of the soil, and the radicle puts forth ramifications, and becomes a root. These changes constitute *germination*. The cotyledons, originally insipid and farinaceous, become sweet and mucilaginous, and furnish materials for the early nutriment of the young plant, before its root and leaves are adequate to their full functions; and vessels are observed ramifying throughout the cotyledons for this purpose, as here represented.



Nourishment.

When the root and stem have acquired a certain degree of vigour, the cotyledons either rot away, or become leaves: and the plant then derives it nourishment by the absorbing powers of the root and leaves, the former collecting materials from the soil, the latter from the atmosphere.

Requisites for vegetation.

The circumstances requisite for the healthy germination or growth of a seed are principally the following: 1. A due temperature, which is always above the freezing point, and below 100°. 2. Moisture in due proportion. 3. A proper access of air, the oxygen of which is slowly converted into carbonic acid. The joint operation of these agents also is required; for seeds exposed to air and moisture, but kept below 32°, will not grow, though they are not injured by the low temperature: nor will a seed vegetate without air, though moisture be present and a sufficient temperature; this is shown by burying seeds deep in the soil, and by the spontaneous vegetation upon newly-turned earth, in which seeds had existed, but through absence of oxygen had been unable to vegetate. Hence in all cases of tillage the seeds should be so sown as that the air may have access; in sandy soils this is easily attained, but in clayey soils the adhesiveness of the materials is often the cause of their unproductiveness.

Air and soil.

1535. As the plant advances to perfection, it becomes dependant upon the air and soil for its nutriment: the roots absorb moisture and other materials; and the leaves, while they exhale moisture, frequently absorb carbon from the carbonic acid present in the atmosphere, and evolve oxygen. This evolution of oxygen takes place while plants are exposed to the solar rays, and appears one of the most efficient causes hitherto suggested of the purification and renovation of the air. In the night-time, the leaves of plants always exhale carbonic acid, and at all times if the leaves be dying or unhealthy. There are also certain plants which appear under all circumstances rather to deteriorate than renovate the air; on the whole, however, the balance is in favour of amelioration (DAVY's *Agricultural Chem.* 4to. p. 195.) though the disappearance of the enormous quantities of carbonic acid gas continually pouring into our atmosphere, can, I think, scarcely be referred to the purifying action of vegetables alone.

Moisture.

Under certain circumstances, the leaves of plants also absorb a considerable portion of aqueous vapour and water, as is shown by the resuscitation of a drooping plant, on sprinkling it with water, or exposing it to a humid atmosphere. It is probable that, in healthy vegetation, the absorption of water by the leaves takes place in the night season chiefly, and that their principal function in the day is that of transpiration,* Upon these subjects the reader may consult SAUSSURE's *Recherches Chimiques sur la Végétation.*

Sap. 1536. The fluid found in the vessels of plants is called their *sap*; it has a motion in the vessels, and appears to rise from the roots in a series of tubes in the alburnum; it then circulates in the leaves, becomes changed considerably in composition, and enters the vessels of the inner bark, enabling it to produce a new layer of wood, and to form the peculiar secretions which belong to it, and which, in smaller quantity, are also found in other parts of the vegetable.

The cause of the motion of the sap has never been satisfactorily accounted for, though it is, perhaps, principally referable to the contraction and expansion produced by changes of temperature.

Ascent. Descent. That the sap ascends in the *alburnum*, and descends in the *liber*, or inner bark, is shown by making an incision into the former and latter. The wound of the one will exude upon its lower surface, and of the other upon its upper surface: and if a circular strip of bark be removed from a small branch of a tree near the stem, there will, of course, be an accumulation of sap in that branch, and its produce of leaves, flowers, and fruit, is often remarkably increased by such an operation.

If the alburnum, on the contrary, of a branch be completely divided, it dies, as nourishment is then excluded; a fact pointed out by Mr. Knight; who has also shown, in proof of the situation of the vessels carrying the ascending sap, that coloured fluids applied to the root always pass upwards in the alburnum only.—*Phil. Trans.* 1801.

Composition of the Sap. 1537. The sap of plants is of very various composition, and contains, besides certain proximate vegetable principles, several saline substances, especially the acetates of potassa, and of lime: it also often exhibits traces of uncombined vegetable acids. The sap of the elm, beech, hornbeam, and birch, have been examined by Vauquelin, (*Annales de Chimie*, xxxi.) Dr. Prout has given some account of the sap of the vine; and Professor Scherer has analyzed the sap of the common maple. (THOMSON'S *System*, iv. 212.) It is, however, almost impossible to collect the ascending sap without admixture of some other juices of the plant, so that the analyses only afford approximations to its real composition.

Heat of plants. 1538. The heat of plants is in many instances above that of the surrounding medium, and there are cases on record in which a very marked elevation of temperature has been observed in them, but upon this subject we have as yet no accurate researches.—SMITH'S *Introduction to Botany*, p. 89.

1539. Though the presence of light, air, and moisture, aided by a due temperature, are the principal requisites for the growth of plants, these are not the only essentials, for they also derive nutriment from the soil, which becomes impoverished by their growth, and ultimately incapable of supporting healthy vegetation, unless aided by manures. It is thus that the alcaline, earthy, and saline ingredients of plants are furnished, and quick-growing vegetables require a constant supply of these substances.

Manures. 1540. *Manures* are of vegetable, animal, or mineral origin. The two former are capable of affording two of the essential ingredients of plants, namely, carbon and hydrogen; they may also yield some of the more immediate principles found in vegetables. The mere existence, however, of vegetable matter in the soil, is not sufficient to constitute it a manure; it must be reduced to a soluble state; to a state in which it can be absorbed by the roots of a growing vegetable; this is often effected by fermentation or putrefaction, or by applying the vegetable matter in a green state, as by ploughing in a green crop. Where the vegetable matter is in an inert insoluble form, it will be of no avail unless rendered active and soluble, which is effected either by mixing it with such kinds of animal matter as undergo quick putrefaction, and are themselves propitious to the growth of vegetables; such, for instance, as dung, rotten fish, or decaying parts of animals; or, by the operation of alcaline bodies, such as quicklime, *&c.*

When newly burned lime is strewed over a soil containing inert vegetable matter, it acts upon it, and renders it more or less soluble; while the lime, by absorbing moisture and carbonic acid, is slaked, and passes into the state of chalk, which is not hurtful to vegetables, and often a very useful addition to the soil: but when limestone contains magnesia, that earth remains caustic, and sometimes proves highly injurious.—Davy's *Agricultural Chemistry*, 4to. p. 234.

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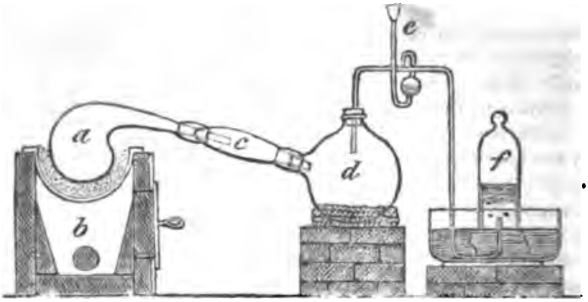
Section II. *Of the Composition and Analysis of Vegetable Substances, and of their ultimate and proximate Principles.*

1541. The *ultimate* principles of vegetable substances are few in number; but by being combined in various proportions, they give rise to a series of compounds materially differing from each other, and which may be called their *proximate* component parts.

Ultimate principles.

Carbon, hydrogen, and oxygen, are the principal ultimate components of vegetables: some afford nitrogen; in some there are traces of sulphur; and in their sap or juices we find small proportions of potassa and of lime, sometimes of soda and of magnesia; these bodies are combined with acids, and chiefly obtained by burning or incineration. It has already been said, that some plants contain silica; sulphate of lime is found in clover, nitrate of potassa in the sap of the sun-flower, and nitrate of soda in barley. Common salt is a very frequent ingredient in marine plants; phosphate of lime is found in oats and some other seeds; and nearly all vegetables yield traces of oxide of iron, and many of oxide of manganese. In Saussure's *Chemical Researches on Vegetation*, and in the fourth volume of Dr. Thomson's *System of Chemistry*, are copious tables, showing the earthy and saline constituents of vegetables.

1542. When vegetable substances are submitted to destructive distillation, the carbon, hydrogen, and oxygen which they contain enter into new arrangements, and a variety of *products* are obtained, differing in quantity and quality according to the nature of the vegetable substance, and varying with the mode of distillation. Water, empyreumatic oil, acids, carbonic oxide and acid, and carburetted hydrogen, are in this way formed; and if the vegetable contain nitrogen, ammonia may be obtained. A portion of charcoal, with the saline and earthy ingredients, remains in the retort. By a careful analysis of these products, the relative proportions of carbon, hydrogen, and oxygen, and of nitrogen, if present, may be judged of. The following form of apparatus may be used in these researches:

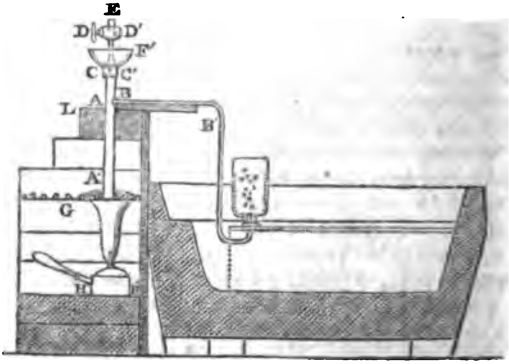


a is a glass or earthen retort, containing the vegetable substance to be decomposed, and placed in a sand heat upon the furnace *b*, which is gradually raised to a red heat. It is connected by the adapter *c* with the receiver *d*, which is kept cool for the condensation of the liquid products; the gases pass into the bell-glass *f* standing over mercury. *e* is a tube of safety, to allow for sudden expansion or contraction; there being in its lower part a small quantity of mercury which is occasionally elevated or depressed. The joints are secured by lute.

Analysis with chlorate of potassa.

1543. An improved mode of ascertaining the relative proportions of the ultimate component parts of vegetable products has been devised by MM. Gay Lussac and Thenard, (*Recherches Physico-Chimiques*, Tom. ii.) It consists in burning the vegetable substance with chlorate of potassa (546.) The requisite proportion of the chlorate, ascertained by previous experiment, is mixed with a given weight of the vegetable matter, and made into a small ball, which is dried, and burned in the apparatus described in the opposite page. The gases are collected over mercury. The carbonic acid is absorbed by *solution of potassa*: if nitrogen be present, it will be found in the residuary gas; if carburetted hydrogen has been disengaged, its quantity and composition may be ascertained by detonation with oxygen. There should, however, always be allowance made for the production of excess of oxygen: thus the quantity of carbon is estimated from that of the carbonic acid formed; the quantity of hydrogen is deduced from that of the oxygen which has disappeared for the production of water; and the quantity of oxygen is learned by the remaining excess.

The details of the process will be found in the fourth volume of M. THENARD's *Traité de Chimie*, with the following arrangement and description of the apparatus.



A hole is made through a brick, L, and the glass tube AA is passed through it as far as to the small lateral tube BB, which passes into the mercurial trough. The lower extremity of the tube rests upon the grate G, where it is to be heated red-hot by charcoal, inflamed by the lamp H. A brass cock is fitted by grinding, to the tube CC. It has a solid plug, DD, in which is a cavity large enough to contain one of the balls to be analyzed, and which is introduced at the opening E. The plug is then turned round, and the ball falls into the red-hot part of the tube, where it burns, the gases passing into the mercurial apparatus. FF is a basin, into which ice may be introduced to keep the metallic parts of the apparatus cool. It is convenient to case the lower part of the tube A in iron, as it is sometimes blown out at that part by the expansion within.

Further directions respecting this process, with some observations upon it by Mr. Daniell, will be found in Mr. Children's translation of M. Thenard's volume on Analysis.

With metallic oxides.

1544. A simpler, and in some respects, preferable means of analyzing vegetable substances, consists in exposing them to heat with certain metallic oxides in vessels which admit of our collecting the residue and products of combustion. For this purpose, procure a copper tube, bored from a solid bar, about twelve inches long, and one-third of an inch internal diameter, with a bent brass tube ground to its open end, to which is attached, also by grinding, a glass tube containing powdered muriate of lime, and bent so as conveniently to pass under the shelf of the mercurio-pneumatic apparatus; the muriate of lime may be kept it its place by some loose amianthus, and the weight of the glass tube should be carefully ascertained. Fill the brass tube loosely with dry amianthus; weigh out 3 grains of the vegetable substance to be analyzed, and mix these intimately with 120 grains of finely-powdered peroxide of copper; put this mixture into the bottom of the copper tube, and afterwards fill it up loosely with oxide of copper; then attach the brass and glass tubes, and arrange the apparatus so that the open end of the latter may be brought under an inverted jar of mercury, and the copper tube placed in a small furnace and surrounded with burning charcoal, taking care to apply the heat in the first instance to the upper part of it, and afterwards, to the bottom containing the vegetable matter; care should be taken to make the whole of the copper tube gradually dull red, and to keep the brass tube as cool as possible by a damp cloth. During this operation the carbon of the vegetable matter will be converted into carbonic acid, and collected over the mercury; the nitrogen, if any, will be mixed with it, and the hydrogen will be converted into water, and absorbed by the muriate of lime. The carbonic acid may be absorbed by liquid potassa, and its bulk furnishes a datum upon which to calculate the proportion of carbon, while the increase of weight in the muriate of lime shows the quantity of water formed, and consequently the quantity of hydrogen in the matter subjected to analysis. If we find the aggregate weight of the carbon and hydrogen, or of the carbon, hydrogen, and nitrogen, equal to that of the original vegetable substance, no oxygen was present; but if there be a deficiency it may be referred to oxygen.

1545. In all analyses thus conducted, the vegetable substance should either be previously perfectly dried, or the quantity of adhering water, if there be any, allowed for in summing up the results; with every precaution, however, the method is open to objections, and liable to several sources of fallacy. Indeed, although I have frequently made such experiments with every possible caution, I have in no one instance gained satisfactory results; the quantity of carbon may, it is true, be obtained with sufficient accuracy; but the greatest difficulty attends the collection of the water which is formed, and all estimates that I have been able to make of the relative proportions of oxygen and hydrogen have been so exceedingly at variance in different trials, as entirely to shake my confidence in the accuracy of the mode of analysis; and the same difficulty occurs in respect to the nitrogen. When, therefore, I see the results of the analysis of a single grain of vegetable matter detailed to the third decimal number, I cannot but suspect that theory has more share in the result than experiment, more especially when such analysis is made the basis of an atomical calculation.

1546. By subjecting different vegetable substances to ultimate analysis, MM. Gay-Lussac and Thenard consider themselves warranted in drawing the following conclusions:

Acid. *a.* A vegetable substance is always acid, when the oxygen which it contains is to the hydrogen, in a proportion greater than is necessary to form water, or where there is *excess of oxygen.*

Resinous. *b.* A vegetable substance is resinous, oily, or alcoholic, where the oxygen is to the hydrogen in a less proportion than in water, or where there is *excess of hydrogen.*

Saccharine. *c.* A vegetable substance is neither acid nor resinous, but saccharine, mucilaginous, *&c.*, where the oxygen and hydrogen are in the same relative proportion as in water, or where there is *no excess of either.*

To the correctness of these results, there are some exceptions which have been pointed out by M. Saussure (THOMSON'S *Annals*, Vol. vi.,) and by Mr. Daniell (*Journal of Science and Arts*, Vol. vi. p. 326,) and which tend considerably to shake our confidence in their entire accuracy.

The following Table exhibits the results of the analysis of several

SUBSTANCES ANALYZED.	Carbon contained in that body.	Oxygen contained in that body.	Hydrogen contained in that body.	Or supposing the oxygen and hydrogen to be in the state of water in the vegetable substance.		
				Carbon.	Water.	Excess of Oxygen.
Sugar . . .	42.47	50.63	6.90	42.47	57.53	0
Gum arabic .	42.23	50.84	6.93	42.23	57.77	0
Starch . . .	43.55	49.68	6.77	43.55	56.45	0
Sugar of milk .	38.825	53.834	7.341	38.825	61.175	0
Oak	52.53	41.78	5.69	52.53	47.47	0
Beech . . .	51.45	42.73	5.82	51.45	48.55	0
Mucous acid .	33.69	62.67	3.62	36.69	30.16	36.15
Oxalic acid . .	26.57	70.69	2.74	33.57	22.87	50,56
Tartaric acid .	24.05	69.32	6.63	24.05	55,24	20.71
Citric acid . .	33.81	59.86	6.33	33.81	52,75	13.44
Acetic acid . ..	50.22	44.15	5.63	50.22	46.91	2.87
						hydrogen in excess
Resin of turpent.	75.94	13.34	10.72	75.94	15.16	8.90
Copal . . .	76,81	10.61	12.58	76.81	12.05	11.14
Wax	81.79	5.54	12.67	81.79	6.30	11.91
Olive oil . .	77.21	9.43	13.36	77.21	10.71	12.08

substances, by the mode above described. THENARD's *Treatise on Chemical Analysis, translated by* A. MERRICK.

Proximate principles.

1547. The *proximate* principles of vegetables are chiefly separable from each other by the action of certain solvents, of which the principal are cold and hot water, alcohol, ether, and a few of the acids. The manner of applying these will be made more obvious by the details in the following sections, than by any general account which could here be given of the various steps of the analysis. The number of proximate principles which are thus capable of being distinguished and separated from each other, is considerable; those which have been most accurately examined are enumerated in the following Table, and will each form the subject of a separate section; while those which are less perfectly known, will be adverted to under the titles of those which they most nearly resemble.

1 Gum.
2 Sugar.
3 Starch.
4 Gluten.
5 Extractive matter and Lignin.
6 Tannin.
7 Colouring matter.
8 Wax.
9 Fixed oil.
10 Volatile oil.
11 Camphor.
12 Resins.
13 Narcotic principles.
14 Bituminous substances.
15 Vegetable acids.
a. Tartaric acid.
b. Oxalic acid.
c. Benzoic acid.
d. Citric acid.
e. Malic acid.
f. Gallic acid.

SECTION III. *Gum.*

Properties.

1548. GUM is contained in considerable quantities in the sap of many vegetables, and frequently appears as a spontaneous exudation. *Gum arabic* may be taken as a specimen of pure gum. Its specific gravity is about 1.4. It has a slightly yellow tint, and is translucent, inodorous, and insipid. It dissolves in water, forming a viscid solution, or *mucilage*, from which it may be obtained in its original state by evaporation; it is insoluble in alcohol, which, therefore causes a white precipitate in its aqueous solutions; it is also insoluble in ether and oils; it undergoes no change by exposure to air, and its aqueous solution does not ferment, but only becomes slightly sour when kept for a long time.

Mucous acid.

1549. Gum is decomposed by sulphuric and nitric acids: the former produces water, acetous acid, and charcoal; the latter, among other products, converts a portion of the gum into a white acid substance, called the *mucous acid*, and which is analogous to that obtained from sugar of milk, or *saccholactic acid*, under which head its preparation is mentioned: malic and oxalic acids are also formed.

Dilute sulphuric, and muriatic acids, dissolve gum without change.

Solvents of gum.

1550. The alcalies, and solutions of the alcaline earths, also dissolve gum, and the addition of acids occasions its partial precipitation without having undergone much apparent alteration. It combines with a few of the other metallic oxides. A strong solution of permuriate of iron, dropped into a concentrated mucilage, forms a brown jelly of difficult solubility. Silicated potassa also occasions a white flaky precipitate in dilute mucilage, and is, according to Dr. Thomson, a very delicate test of gum. By mixing caustic ammonia with a boiling solution of gum, and then adding subnitrate of lead, Berzelius obtained a white precipitate (*gummate of lead*) composed of

Gum	61.75
Oxide of lead . .	38.25
	100.

If this compound be regarded as consisting of 1 proportional of gum and 1 of oxide of lead, the number 181 might be assumed as the representative of gum, for 38.25 : 61.75 : : 112 : 180.8. But if we consider it as a compound of 2 of gum and 1 of oxide, then 90.5 would be the equivalent of gum, and the following numbers nearly agree with its composition, as deduced from experiment:

6 Proportionals of oxygen	8 × 6	=	48.0	= 53.3
6 . . . . hydrogen	1 × 6	=	6.0	= 6.6
6 . . . . carbon	6 × 6	=	36.	= 40
			90	99.9

1551. Submitted to destructive distillation, gum affords carbonic acid and carburetted hydrogen gases, empyreumatic oil, water, and a considerable quantity of impure acetic acid, once considered as a peculiar acid, and distinguished by the term *pyromucous acid.*

Other gums. 1552. There are several varieties of gum differing a little from each other. *Cherry-tree gum* and *gum tragacanth* do not dissolve in cold water, but in other respects their properties resemble those of gum arabic. To these varieties the generic term of *Cerasin* has been given by some chemists.

* * *

SECTION IV. *Sugar.*

1553. SUGAR may be extracted from the juice of a number of vegetables, and is contained in all those having a sweet taste; that which is commonly employed is the produce of the *arundo saccharifera*, or *sugar-cane*, a plant which thrives in hot climates. Its juice is expressed and evaporated with the addition of a small quantity of lime, until it acquires a thick consistency; it is then transferred into wooden coolers, where a portion concretes into a crystalline mass, which is drained and exported to this country under the name of *muscovado*, or *raw sugar*. The remaining liquid portion is *molasses*, or *treacle*.

Preparation.

1554. The following is a sketch of the process by which raw sugar is purified in this country.

Purification. Raw sugar is chosen by the refiner by the sharpness and brightness of the grain, and those kinds are preferred which have a peculiar grey hue. Soft-grained yellow sugars, although they may be originally whiter, are not so fit for the purposes of the manufactory, and it is for this reason that sugars from particular countries are never used: such are those from the East Indies, Barbadoes, *&c.* They do not possess the property of crystallizing so perfectly, and approach in this respect to the nature of grape sugar.

Two kinds of saccharine matter.

There appear to be two perfectly distinct kinds of saccharine matter; one, when pure, is transparent and colourless, and crystallizes under proper management in a regular form, generally in flattened six-sided prisms; the other is uncrystallizable, and generally highly charged with colouring matter. This colouring matter is not, perhaps, essential to it, but may arise in the present case from the effect of fire, by the agency of which it is peculiarly prone to decomposition. We may mention, as familiar instances of these two, *white-sugar-candy* and *treacle*. The juice of the cane is composed of these ingredients, and though they are in some degree separated in our Indian colonies by the process of evaporation and filtration, yet the raw sugar which we receive contains still much of the latter combined with the former. The process of refining consists in further separating the two.

Lime water. Bullock's blood.

The proper sugar being selected, the *pans*, which resemble in some measure those used in the West Indies, are charged with a certain portion of lime-water, with which bullocks' blood is well mixed by agitation. They are then filled with the sugar, which is suffered to stand a night to dissolve. The use of the lime-water is not, as is generally supposed, to neutralize any free acid in the raw material: but, by combining with the molasses, to render it more soluble, and thus to facilitate its separation from the pure solid sugar. In the purer kinds, and more especially when the refined is again melted over for the purpose of bringing it to its utmost degree of purity, lime is not used, the quantity of molasses being so small as to be easily removed by the agency of water alone.

Concentration.

Fires are lighted under the pans early in the morning, and when the liquid begins to boil, the albumen of the blood coagulates and rises to the top, bringing all the impurities of the sugar with it. These are taken off with a skimmer. The liquid is kept gently simmering and continually skimmed, till a small quantity, taken in a metallic spoon, appears perfectly transparent: this generally takes from four to five hours. The whiteness of the sugar is not at all improved by this process, but is even sometimes deteriorated from the action of the fire: it only serves to remove all foreign impurities. When the solution is judged to be sufficiently clear, it is suffered to run off into a large cistern. The pans are then reduced to half their size by taking off their fronts, and a small quantity is returned into each. The fires are now increased, and the sugar made to boil as rapidly as possible, till a small quantity taken on the thumb is capable of being drawn into threads by the fore-finger. Nothing but practice can ascertain the exact point at which the boiling should be stopped: if it is carried too far, the molasses is again bound up with the sugar; and if it is not carried far enough, much of the sugar runs off with the molasses in the after-process. When this point is ascertained, the fire is instantly damped, and the boiling sugar carried off in basins to the *coolers;* a fresh quantity is then pumped into the pans, which is evaporated in the like manner.

Granulation.

When the sugar is in the coolers, it is violently agitated with wood-

Candying.

en oars till it appears thick and granulated, and a portion taken on the finger is no longer capable of being drawn into threads. It is upon this agitation in the cooler that the whiteness and fineness of grain in the refined sugar depends. The crystals are thus broken whilst forming, and by this means the whole is converted into a granular mass, which permits the coloured liquid saccharine matter to run off, and which would be combined with the solid if suffered to form in larger crystals. This granular texture, likewise facilitates the percolation of water through the loaves in the after-process, which washes the minutely-divided crystals from all remaining tinge of the molasses. That this is the true theory of the whitening of sugar by the process of refining, appears from a comparison with the process for making candy. In this latter, the raw material is cleared and boiled exactly in the same manner; but instead of being put into coolers and agitated, it is poured into pots, across which threads are strung, to which the crystals attach themselves: these are set in a stove, and great care is taken not to disturb the liquid, as upon this depends the largeness and beauty of the candy. In this state it is left for five or six days, exposed to a heat of about 95°, when it is taken out and washed with lime-water: this takes off the molasses from the outside, but a great quantity is combined in the crystals, and the consequence is, that candy is never whiter than the sugar from which it is made.

Claying.

When the sugar has arrived at that granular state in the coolers above described, it is poured into conical earthen moulds, which have previously been soaked a night in water. In these it is again agitated with sticks, for the purpose of extricating the air-bubbles which would otherwise adhere to the sugar and the moulds, and *leave the coat of* the loaf rough and uneven. When sufficiently cold, the loaves are raised up to some of the upper floors of the manufactory, and the paper stops being removed from their points, they are set, with their broad ends upward, upon earthen pots. The first portions of the liquid molasses soon run down, and leave the sugar much whitened by the separation. This self-clearance is much assisted by a high temperature; and when it is perfected, pipe-clay, carefully mixed up with water to the consistence of thick cream, is put upon the loaves to the thickness of about an inch: the water from this slowly percolates the loaves: and, washing the solid sugar from all remains and tinge of the molasses, runs into the pots. The clay is of no other use than to retain the water, and prevent its running too rapidly through the mass, by which too much of the sugar would be dissolved: a sponge, dipped in water, acts in the same manner. The process of *claying* is repeated four or five times, according to the nature of the sugar, and the degree to which it has been boiled. When the loaves are perfectly cleansed from all remains of the coloured fluid, they are suffered to remain some time for the water to drain off; when this is completed, they are set, with their faces down, when all remains of it return from their points, and it is equally diffused throughout: they are then set in a stove, heated to about 95°, and thoroughly dried.

Bastard.

The syrup, or the mixed solution of sugar and molasses which runs into the pots, is mingled in the next boilings with the solution of raw sugar in the pans, and again evaporated. It is divided according to its fineness; the first running containing, of course, more molasses, is reserved for the coarser loaves; whilst the last, being little else than a solution of sugar, is boiled into loaves, of the same degree of fineness as those from which it ran. The lowest syrups are boiled into what is called *bastard sugar*, from which the molasses runs with very little mixture of the solid sugar. This is called *treacle*, and is totally incapable of further crystallization.

Treacle.

The produce of 1 cwt. of raw sugar worked in this manner is, upon an average,

63 lbs refined
18 — bastard
27 — molasses
4 — lost weight, dirt, &c.

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The process above described may almost be considered as mechanical. The only truly chemical parts of it are the clearing with blood, and the use of lime-water, which, leaving the solid sugar untouched, combines with the molasses, and rendering it in some measure saponaceous, facilitates its solution during the percolation of the water.

Attempts have lately been made to whiten the sugar during its boiling, by the addition of charcoal. This destroys some of the colouring matter of the molasses, and tends materially to whiten the sugar, especially if the charcoal employed be partly of animal origin.

Charcoal.

Another attempt has been made to improve the process of claying, by the substitution of a strong solution of very white sugar for the clay. The idea was, that the water having a stronger affinity for the molasses than for the solid sugar, would, in its passage through the loaves, wash away the former, and leave the latter in its place, and that more weight and a closer grain would thus be obtained. The idea was ingenious, but the advantages scarcely counterbalanced the additional expense of preparing the solution of fine sugar in the first instance.

Saturated syrup.

1555. Sugar may be obtained from the sap of many other plants. It exists in large quantity in the sugar maple (*acer saccharinum*), and in the root of the common beet (*beta vulgaris*). In many ripe fruits sugar is a predominating ingredient; and in dried grapes, figs, &c., it is often seen as a superficial incrustation. Though these kinds of sugar differ a little from each other, they can scarcely be regarded as distinct species.

Sugar from other plants.

1556. *Honey* is also a variety of sugar containing a crystallizable and an uncrystallizable portion, the predominance of one or other of which give to it its peculiar character; they may be partially separated by mixing the honey with alcohol, and pressing it in a linen bag; the liquid sugar being the most soluble, passes through, leaving a granular mass, which forms crystals when its solution in boiling alcohol is set aside. Honey also frequently contains wax, and a little acid matter.

Animal sugar. Honey.

1557. Sugar is a white brittle substance of a pure sweet taste, soluble in its own weight of water at 60°. Boiling water dissolves a considerably larger quantity. This solution is called *syrup*; it is viscid, and furnishes crystals in the form of four and six-sided prisms, irregularly terminated. Sugar is soluble in alcohol, but much more sparingly so than in water.

1558. Nitric and sulphuric acids decompose sugar; the former con-

Actions of acids.

verts it into oxalic acid; the latter evolves charcoal and produces water and acetous acid.

Action of alcalis.

1559. The alcalis dissolve sugar, and destroy its sweet taste, which re-appears if an acid be added. When, however, the alcalis are left for a long time in the contact of sugar they effect a more important change, becoming carbonated and converting the sugar into gum. From a solution of sugar in lime-water, Mr. Daniell, who has obligingly furnished me with the principal materials of this section, obtained crystals of carbonate of lime and a portion of gum. The addition of phosphuret of lime to syrup produces an analogous change.—*Journal of Science and the Arts*, Vol. vi. p. 32.

Of protoxide of lead.

1560. When protoxide of lead is digested with sugar and water, a portion is dissolved and afterwards separates in the form of a white insipid powder (*saccharate of lead*,) insoluble in water and composed, according to Berzelius, of

Sugar	41.74
Oxide of lead	58.26
	100.00

Action of caloric.

1561. When sugar is exposed to heat it fuses, becomes brown, evolves a little water, and is resolved into new arrangements of its component elements. If suddenly elevated to a temperature of about 500°, it bursts into flame.

1562. The relative proportions of elements in gum and sugar appear from the experiments of Gay-Lussac (page 17,) to be nearly the same. The analyses of these two substances by Berzelius afforded slight differences only; according to him they contain

$$\left.\begin{array}{ll}\text{Carbon} \ldots\ldots & 41.906\\ \text{Oxygen} \ldots & 51.306\\ \text{Hydrogen} \ldots & 6.788\end{array}\right\} = \begin{array}{l}\text{Gum} \ldots \\ 100 \ldots \\ \quad \ldots\end{array}\left.\begin{array}{l}44.200\\ 49.015\\ 6.785\end{array}\right\} = \begin{array}{c}\text{Sugar}\\ 100\end{array}$$

The equivalent of sugar, deduced from the analysis of the compound with oxide of lead, provided we regard that compound as containing 1 proportional of each of its components, is 80.2 a number not perfectly reconcileable with the ultimate of analysis of Berzelius, who regards sugar as composed of

6	Proportionals of carbon. .	6×6 =	36.	.44. 4
5	- - - - - - - - oxygen	8×5 =	40.	.49.38
5	- - - - - - - - - hydrogen	1×5 =	5.	6.17
			81.	99.95

Manna.

1563. *Manna* is an exudation from the *Fraxinus Ornus*, a species of ash, growing in Sicily and Calabria. It has a sweet and somewhat nauseous taste, and is used in medicine as a mild aperient. It is very soluble in water, and more soluble in alcohol than cane sugar; the latter solution deposits it in the form of a white spongy mass. Digested in nitric acid, it yields both oxalic and saclactic acids. Its solution in water does not appear susceptible of vinous fermentation.

SECTION V. *Starch.*

1564. STARCH, or *Fecula*, may be separated from a variety of vegetable substances; it is contained in the esculent grains, and in many roots. The process for obtaining it consists in diffusing the powdered grain or the rasped root in cold water, which becomes white and turbid; the grosser parts may be separated by a strainer and the liquor which passes deposits the starch, which is to be washed in cold water and dried in a gentle heat.

Process for obtaining starch.

1565. The common process for obtaining the starch of wheat consists in steeping the grain in water till it becomes soft; it is then put into coarse linen bags, which are pressed in vats of water: a milky juice exudes, and the starch falls to the bottom of the vat. The supernatant liquor undergoes a slight fermentation, and a portion of alcohol and a little vinegar is formed, which dissolves some impurities in the deposited starch; it is then collected, washed, and dried in a moderate heat, during which it splits into the columnar fragments which we meet with in commerce, and which are generally rendered slightly blue by a little smalt.

Properties of starch.

1566. Pure starch is a white substance, insoluble in cold water, but readily soluble at a temperature between 160° and 180°. Its solution is gelatinous, becomes mouldy and sour by exposure to air, and by careful evaporation yields a substance resembling gum in appearance, which is a compound of starch and water. Starch is insoluble in alcohol and in ether, and occasions no precipitate in the greater number of metallic solutions; in solution of subacetate of lead, however, it occasions a copious precipitate. The most characteristic property of starch is that of forming a blue compound with iodine; it may be obtained by adding an aqueous solution of iodine to a dilute solution of starch.

Insoluble in alcohol, &c.

Precipitates oxide of lead.

Forms a blue with iodine.

Sulphuric and nitric acids dissolve starch, and slowly decompose it, or resolve it into new compounds. Dilute nitric acid dissolves it without decomposition, forming a greenish solution, which deposits starch upon the addition of alcohol. It is slowly soluble in muriatic acid, and insoluble in acetic acid.

Soluble in acids.

Potassa, triturated with starch, forms a compound which is soluble in water.

Unites to potassa.

Infusion of galls occasions a precipitate in the solutions of starch, which re-dissolves by heating the liquid to 120°. This property Dr. Thomson considers as characteristic of starch.

Precipitated by tannin.

1567. By digesting subnitrate of lead in a boiling solution of starch, Berzelius obtained an insoluble compound, which he has termed *amylate of lead*, consisting of

72	starch.
28	oxide of lead.
100	

1568. It appears by a reference to the ultimate elements of starch and sugar, that they differ little in composition, and it is therefore not surprising that the former is easily convertible into the latter.

1569. The change of starch into sugar is always observed during the

Germination. germination of seeds (1534), and in the process of *malting* a similar conversion is effected.

Malting. *Malt* is barley which has been made to germinate to a certain extent, after which the process is stopped by heat. The barley is steeped in cold water, and is then made into a heap, or *couch*, upon the maltfloor: here it absorbs oxygen and evolves carbonic acid; its temperature augments, and then it is occasionally turned, to prevent its becoming too warm. In this process the radicle lengthens, and the plume, called by the maltsters the *acrospire*, elongates; and when it has nearly reached the opposite extremity of the seed, its further growth is arrested by drying at a temperature slowly elevated to 150° or more. The malt is then cleansed of the rootlets.

According to Dr. Thomson, barley loses about 8 *per cent*. by converting it into malt, of which

1.5	is carried off by the steep-water
3.0	dissipated in the floor
3.0	roots separated by cleansing
0.5	waste
8.0	

1570. The following comparative analysis of unmalted and malted barley shows the change which has taken place in the operation.

Gum	5	*14*
Sugar	4	*16*
Gluten	3	*1*
Starch	88	*69*
	100 barley.	*100* malt.

Conversion of starch into sugar by sulphuric acid. 1571. Another mode of converting starch into sugar was discovered by M. Kirchoff; it consists in boiling it with very dilute sulphuric acid. A pound of starch may be digested in six or eight pints of distilled water, rendered slightly acid by two or three drachms of sulphuric acid. The mixture should be simmered for a few days, fresh portions of water being occasionally added to compensate for the loss by evaporation. After this process the acid is saturated by a proper proportion of chalk, and the mixture filtered and evaporated to the consistence of syrup; its taste is sweet, and, by purification in the usual way, it affords crystallized sugar. MM. de la Rive and Saussure have shown that the contact of air is unnecessary in the above process; that no part of the acid is decomposed, no gas evolved, and that the sugar obtained exceeds by about one-tenth, the original weight of the starch. M. de Saussure, therefore, concludes that the conversion of starch into sugar depends upon the solidification of water, a conclusion strengthened by the following comparative analysis.—Thomson's *Annals*, Vol. ii.

	100 Parts of Starch contain	100 Parts of Starch Sugar contain
Carbon	45.39	37.29
Oxygen	48.31	55.87
Hydrogen	5.90	6.84
Nitrogen	0.40	0.00
	100.00	100.00

1572. This analysis of starch is somewhat at variance with that given by Gay-Lussac; indeed the small portion of nitrogen cannot be considered as an essential component. Berzelius has given the followlowing as the component parts of starch.—Thomson's *Annals*, Vol. v.

Carbon	43.481
Oxygen	48.455
Hydrogen	7.064
	100.000

If we regard the amylate of lead as consisting of 2 proportionals of starch, and 1 of oxide of lead, the number 144. will be the equivalent of starch, the constituents of which may be thus expressed:

10 Proportionals of	carbon	6 × 10 = 60.	42.2
9 - - - - - - - - -	oxygen	8 × 9 = 72.	50.7
10 - - - - - - - - -	hydrogen	1 × 10 = 10.0.	7.
		142.	99.9

These numbers closely approximate to the results of Gay-Lussac and Thenard's analysis.

1573. When starch is exposed to a temperature between 600° and 700° it swells, and exhales a peculiar smell; it becomes of a brown colour, and in that state is employed by calico-printers under the name of *British gum*. It is soluble in cold water, and does not form a blue compound with iodine. Vauquelin found it to differ from gum in affording oxalic instead of mucous acid, when treated with nitric acid. British gum.

1574. Proust has described a principle in barley, to which he has given the name of *Hordein*; it appears, however, to be a variety of starch, and can scarcely be admitted as a distinct vegetable principle. —*Annales de Chimie et Phys*. Tom. v. Hordein.

1575. The following are the principal varieties of starch: Varieties.

i. *Arrow-root*, the fecula of the *Marantha Arundinacea*.

ii. *Potatoe Starch*, obtained by reducing potatoe to a pulp, and washing it with cold water upon a sieve; the fecula is deposited in the form of a fine white powder, heavier than common starch, but possessed of its essential characters.

iii. *Sago*, extracted from the pith of several species of palm, growing in the East India islands.

iv. *Tapioca* and *Cassava*, prepared from an American plant, the *Iatropha Manihat*.

v. *Salop*, obtained from the roots of several species of *Orchis*.

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Section VI. *Gluten*.

1576. Gluten may be obtained from wheat-flour, by forming it into a paste and washing it under a small stream of water. The starch is thus washed away, and a tough elastic substance remains, which is gluten. Extraction.

Properties.

Its colour is grey, and, when dried, it becomes brown and brittle. It is nearly insoluble in water and in ether. When allowed to putrefy it exhales an offensive odour, and when submitted to destructive distillation it furnishes ammonia, a circumstance in which it resembles animal products. Most of the acids and the alcalis dissolve it.

Partly soluble in alcohol.

1577. Acted upon by alcohol, a portion of gluten is dissolved, and the solution, after having remained to deposit a little extraneous matter, affords, on evaporation, a peculiar substance of a yellowish colour, brittle, and having a balsamic taste. The undissolved portion of the gluten forms soapy compounds with the alcalis, and instead of fermenting like the original gluten, exhales the odour of putrid urine. Hence it appears that, by the action of alcohol, gluten is separated into two principles, the one soluble and the other insoluble in that menstruum. M. Taddei, the author of these researches, calls the former *Gliadine*, and the latter *Zimoma.*—*Giornale di Fisica*, ii. p. 360.

1578. Gluten is an essential ingredient in wheat-flour, and contributes much to its nutritive quality; and gives considerable tenacity to its paste.

Vegetable albumen.

1579. A substance, much resembling gluten, has been found in the juices of certain vegetables, especially in those which are milky and coagulable by acids. It is contained in the sap of the houseleek, of the cabbage, and of most of the cruciform plants. Submitted to destructive distillation, it affords ammonia, and is in other respects similar to the animal principle, called albumen; hence it has been termed *vegetable albumen.*

Bird-lime.

1580. *Caoutchouc* and *Bird-lime* may also be considered as allied to gluten. These substances are insoluble in water and in alcohol, but they are soluble in pure sulphuric ether. Caoutchouc is highly inflammable, burning with a bright flame which throws off much charcoal. When heated it softens, and is in that state soluble in some of the fixed oils. It is said to dissolve easily in oil of cajeput. These solutions are sometimes used as varnishes, but with the exception of that in ether, they remain clammy.

1581. The principles which have now been adverted to, *viz.*, sugar, starch, gum or mucilage, and gluten, constitute the principal nutritive ingredients in most of the esculent vegetables. Wheat grown in this country contains from 18 to 24 *per cent.* of gluten, the remainder being principally starch. The wheat of the south of Europe generally contains a larger quantity of gluten, and is therefore more excellent for the manufacture of macaroni, vermicelli, and other preparations requiring a glutinous paste. The excess of gluten in wheat-flour compared with other grain, renders it peculiarly fit for making bread; for the carbonic acid, extricated during the fermentation of the paste, is retained in consequence of its adhesiveness, and forms a spongy and light loaf.

A hundred parts of barley contain upon an average 80 parts of starch, 6 of gluten, and 7 of sugar, the remaining 7 parts being husk.

From 100 parts of rye Sir Humphry Davy obtained 61 parts of starch and 5 of gluten.

From 100 parts of oats he procured 59 of starch, 6 of gluten, and 2 of sugar.

100 parts of pease afforded about 50 of starch, 3 of sugar, 4 of gluten, and a small portion of extractive matter.

100 parts of potatoe yield, upon an average, 20 parts of starch; they may be considered in general as containing from one-fourth to one-fifth of their weight of nutritive matter.

The turnip, carrot, and parsnip, chiefly contain sugar and mucilage: 1000 parts of common turnips give about 34 of sugar, and 7 of mucilage; 1000 parts of carrots furnish about 95 of sugar, and 3 of mucilage; and the same quantity of parsnips afford 90 of sugar and 9 of mucilage. The loss of weight in the above cases is referable to water, and inert vegetable matter possessed of the properties of woody fibre. (*See the Table at the end of Section* xviii.

SECTION VII. *Extractive Matter and Lignin.*

1582. BY the term *extract, or extractive principle,* we mean a substance contained in the greater number of vegetables, and generally forming the principal ingredient in the pharmaceutical preparations called *extracts.* It possesses the following properties. It is soluble in water, Properties. and the solution is of a brown colour. It is insoluble in ether, but it is soluble in alcohol containing a small portion of water. By repeated solutions and evaporations it may be rendered scarcely soluble in water. Solutions of chlorine, of many of the acids, and of most of the metallic oxides, occasion precipitates in the aqueous solution of extractive.

1583. The following substances may be considered under this head, though many of them are obviously widely different from extractive matter.

1584. *Ulmin.* This substance was first noticed by Klaproth, spontaneously exuding from the elm. From the observations of Berzelius, it exists in the bark of many other trees, and may be obtained by digestion in alcohol and cold water; the action of hot water afterwards dissolves the ulmin.—THOMSON'S *Annals*, Vol. ii.

Ulmin is of a dark brown colour, with scarcely any taste or smell. It is sparingly soluble in water and in alcohol, but readily soluble in a weak solution of carbonate of potassa. Very few of the metallic salts occasion a precipitate in its solution. The exudation from the elm is generally combined with carbonate of potassa, and is therefore readily soluble in water.

1585. *Polychroite.* This term has been applied to the extract of saffron (*Annales de Chim.* Tom. lxxx.) It is of a deep yellow colour, deliquescent, readily soluble in water and in alcohol, but insoluble in pure sulphuric ether. Exposure to the solar rays soon destroys the colour of its aqueous solution. Sulphuric acid renders it blue, and nitric acid green: solutions of lime and baryta produce yellow and red precipitates; subacetate of lead throws down a deep yellow precipitate, and nitrate of mercury separates a red powder.

1586. *Hematin.* This peculiar substance was first recognised by Chevreul in the colouring matter of *log-wood* (*Ann. de Chim.* Tom. lxxxi.) It may be obtained by digesting logwood in water of the temperature of 125°. Filter, evaporate carefully to dryness, and digest the residue for 24 hours in alcohol of the specific gravity of .837. Filter the alcohol; concentrate the solution by evaporation, add a portion of water, evaporate a little further, and set the solution aside: crystals are deposited which, when washed with alcohol and dried, are pure hematin.

Hematin is of a reddish colour; its taste is somewhat bitter, and its aqueous solution is yellow when cold, but orange-red at the temperature of boiling-water. Sulphuric acid added to this solution renders it reddish yellow. The alcalis give it a purplish tint.

1587. *Bitter principle.* By evaporating an infusion of quassia, a substance is obtained of an intensely bitter taste, and of a brownish yellow colour, which is readily soluble in water and in alcohol. Nitrate of silver, and acetate of lead, are the only precipitants of its aqueous solution. It is probable that the same substance exists in other bitter vegetables, and Vauquelin has discovered it in the fruit of the *colocynth*, and in the root of *white briony*.—THOMSON's *System*, Vol. iv.

1588. By digesting indigo, silk, and a few other substances in nitric acid, an intensely-bitter matter is formed, called by Welther the *yellow bitter principle* (*Annales de Chim.* Tom. xxix.) Chevreul has rendered it probable that this is a compound of a peculiar vegetable principle with nitric acid. It is crystallizable, burns like gunpowder and detonates when struck with a hammer.

1589. *Picrotoxin.* This is a bitter poisonous substance contained in the *Cocculus Indicus*. It may be obtained by the following process:—Add acetate of lead to a decoction of the berries, as long as any precipitate falls: filter, evaporate, and digest the extract in highly-rectified alcohol; evaporate to dryness, and agitate the remaining matter with a little water; the picrotoxin remains in the form of white prismatic crystals of a bitter taste.

1590. Picrotoxin is difficultly soluble in water. Alcohol of the specific gravity of 810, dissolves one-third its weight. It is soluble in weak solutions of the pure alcalis. It combines with the acids, and forms compounds, some of which are crystallizable, but they require further examination before we can venture to give this substance a place among the narcotic salifiable bases.—BOULLAY, *Journal de Pharmacie*. v.

1591. *Nicotin.* This is a principle existing in tobacco. It was obtained by Vauqelin by the following process (*Ann de Chim.* lxxi.): Evaporate the expressed juice to one-fourth its bulk; and, when cold, strain it through fine linen; evaporate nearly to dryness; digest the residue in alcohol; filter and evaporate to dryness; dissolve this again in alcohol, and again reduce it to a dry state. Dissolve the residue in water, and saturate the acid which it contains with weak solution of potassa, introduce the whole into a retort, and distil to dryness; re-dissolve, and again distil three or four times successively. The nicotin will thus pass into the receiver, dissolved in water, from which solution it may be obtained by very gradual evaporation.

Nicotin is colourless, acrid, soluble in water and in alcohol, volatile, and highly poisonous.

1592. *Asparagin.*—MM. Vauquelin and Robiquet obtained this substance in a crystalline form by evaporating the juice of asparagus. It has a cool and slightly nauseous taste, and when burned emits acrid vapours, and leaves no traces of alcali.—*Annales de Chimie*, Tom. iv.

1593. *Fungin.* This name has been given by Braconnot to a substance contained in the fleshy part of mushrooms (*Ann. de Chim.* lxxix.) It is insoluble in water and in alcohol, and scarcely acted upon by the alcalis, or by dilute acids. It is the substance which remains after the mushroom has been deprived of every thing soluble in alcohol and in water.

1594. *Inulin.* The roots of elecampane, when boiled in water, furnish a decoction, which, on cooling, deposits a white powder, in many respects resembling starch. It, however, differs in several properties from that principle, and has hence been considered a peculiar vegetable substance.—THOMSON's *System*, Vol. iv.

1595. *Emetin.* To obtain emetin, digest powdered ipecacuanha in alcohol, filter, evaporate carefully to dryness, and re-dissolve in cold water. To this solution add carbonate of baryta, filter, and again evaporate to dryness; digest this residuum in alcohol, and a solution is obtained, which by careful evaporation, affords a reddish-brown substance, soluble in alcohol and in water, and precipitable by sub-acetate of lead; its taste is acrid and bitter, and it is highly emetic.—MM. MAGENDIE and PELLETIER, *Annales de Chimie et Physique*, Vol. iv.

1596. *Woody fibre.* The term *lignin* has been applied to the fibrous substance which remains, after digesting wood in water and in alcohol. It is insipid, and exposed to destructive distillation, affords a considerable quantity of vinegar tainted by empyreumatic oil, and containing a little ammonia. The charcoal which remains is light, brittle, shining, and easily incinerated. The relative quantity, yielded by different woods, has already been adverted to (386.)

1597. We are indebted to M. Braconnot for some highly interesting experiments, relating to the action of sulphuric acid on wood (*Ann. de Chim. et Phys.* xii. 172.) In the course of these researches, he triturated 25 parts of hempen cloth with 34 of the acid; it acquired the consistency of mucilage, which, after 24 hours, was almost entirely soluble in water. The diluted liquor was saturated with chalk, filtered, and evaporated to the consistency of syrup; it deposited sulphate of lime, and was then further evaporated to dryness, when a substance, having the characters of gum, was obtained. In another experiment, 24 parts of lignin were reduced to gum by 34 of sulphuric acid; this acid mixture, diluted with water, and boiled for 10 hours, became sweet; the acid was then separated by chalk, and the liquor, on due evaporation, afforded a crystallizable sugar.

Moistened saw-dust, heated in a platinum crucible with its weight of caustic potassa, afforded a matter soluble in water, and which, upon the addition of an acid to neutralize the alcali, yielded a substance having the properties of *ulmin.*

1598. *Suber* or *Cork.* This is a light, soft, elastic, and combustible substance, burning with a bright flame and leaving a bulky charcoal. Its principal peculiarity is, that by digestion in nitric acid, it is converted into an orange-coloured mass, which furnishes to water a peculiar acid matter, which has been termed *suberic acid.* Chevreul has found in it resin, oil, and a peculiar matter which he calls *Cerin.*—See WAX (1622.)

1599. *Cotton* is a downy substance found in the seed-pods of the different species of *gossypium.* It is insoluble in water and in dilute alcaline and acid solutions. It combines with several of the metallic oxides, which are therefore used as intermedes, or *mordants*, in the art of dyeing. Acetate of alumina is principally employed for this purpose.

1600. *Medullin* is a term given by Dr. John to the pith of the sunflower and some other plants; it is insipid, inodorous, insoluble in water and alcohol, and affords oxalic acid when treated by nitric acid; submitted to destructive distillation, the products abound in ammonia.

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SECTION VIII. *Tannin.*

Extraction. 1601. TANNIN, or the astringent principle, is contained in many vegetables. It may be procured by digesting bruised gall-nuts, grape-seeds, oak-bark, or catechu, in a small quantity of cold water. The solution affords, when evaporated, a substance of a brownish-yellow colour, extremely astringent, and soluble in water and in alcohol.

The purest form of tannin appears to be that derived from bruised grape-seeds, but even here it is combined with other substances, from which it is perhaps scarcely separable, and among the numerous processes which have been devised for procuring pure tannin, there is none that answers the intended purpose. I have never been able to obtain it of greater apparent purity than by digesting powdered catechu in water at 33° or 34°, filtering and boiling the solution, which, on cooling, becomes slightly turbid, and is to be filtered again, and evaporated to dryness; cold water, applied as before, extracts nearly pure tannin.

Properties. 1602. The most distinctive character of tannin is that of affording an insoluble precipitate when added to a solution of isinglass, or any other animal jelly. Upon this property the art of tanning depends, for which oak-bark is generally employed; the barks, however, of many other trees may occasionally be substituted. The following Table, drawn up by Sir Humphry Davy, exhibits the average quantity of tan contained in 480 lbs. of different barks:—*Agricultural Chemistry*, 4to. p. 79.

	lbs.
Average of entire bark of middle-sized Oak, cut in spring	29
——— of Spanish Chestnut	21
——— of Leicester Willow, large size	33
——— of Elm	13
——— of Common Willow, large	11
——— of Ash	16
——— of Beech	10
——— of Horse Chestnut	9
——— of Sycamore	11
——— of Lombardy Poplar	15
——— of Birch	8
——— of Hazel	14
——— of Black Thorn	16
——— of Coppice Oak	32
——— of Oak cut in autumn	21
——— of Larch cut in autumn	8
White interior cortical layers of Oak-bark	72

Union with other bodies. 1603. Tan forms a precipitate with solution of starch, with gluten and albumen, and with many of the metallic oxides. An account of the precipitates formed in metallic solutions by infusion of galls, will be found under the article *Gallic Acid* (1785) but these precipitates are very complex, and vary in composition. Metallic oxides.

1604. If the solution of tan, obtained as above-described from catechu, be added to acetate of lead, an insoluble *tannate of lead* falls, composed, according to Berzelius, of 100 tannin + 52 oxide of lead. Now, if we suppose that tannin forms definite compounds with the metallic oxides, in the manner of a vegetable acid, the number 215.3 will be its representative, as deduced from the above datum.

1605. Mr. Hatchett has shown that tan may be formed artificially by digesting charcoal in dilute nitric acid during several days; it is at length dissolved, and a reddish brown liquor is obtained, which furnishes, by careful evaporation, a brown glossy substance, amounting to about 120 parts from 100 of charcoal. Artificial tannin.

This *artificial tannin* appears to differ in one circumstance only from natural tannin, which is, that it resists the action of nitric acid, by which all the varieties of natural tannin are decomposed, though some are more capable of resisting its action than others.

Artificial tannin has a bitterish astringent taste, is soluble in water and alcohol, and forms an insoluble precipitate in solutions of animal gelatine, the precipitate consisting, according to Mr. Hatchett, of

36	Tannin.
64	Gelatine.
100	

Muriatic and sulphuric acids occasion brown precipitates, in solution of artificial tan, which are soluble in hot water. It combines with the alcalis, and forms a precipitate of difficult solubility in aqueous solutions of lime, baryta, and strontia, and in most metallic solutions; these precipitates are of a brown colour. Actions of acids.

1606. A variety of artificial tan is formed by digesting camphor and resins in sulphuric acid till the liquor becomes black, and on being poured into water, deposits a black powder, which, by digestion in alcohol, furnishes a brown matter, soluble in water, and forming an insoluble precipitate with gelatine.—HATCHETT, *Phil. Trans.* 1805, 1806.

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SECTION IX. *Colouring Matter.*

1607. THE colouring matter of vegetables appears to reside in several of their principles, and is therefore very differently acted on by solvents. Its extraction, and transfer to different substances, constitutes the *art of Dyeing*.

1608. Different materials not only possess very different attractions for dye stuffs, but they absorb the colouring matter in very different proportions. Wool appears in this respect to have the strongest attraction for colouring substances: silk comes next to it; then cotton; and, lastly, hemp and flax.

1609. Colours have been divided by Dr. Bancroft, in his work on *permanent Colours*, into *substantive* and *adjective*. The former communicate colour without the intervention of any other substance. They have an attraction for the fibre of cloth or linen, and are permanently retained. The latter require the intervention of some body, possessed of a joint attraction for the colouring material and stuff to be dyed. The substance capable of thus fixing the colour, has been called a *basis*, or *mordant*.

Mordants. 1610. The mordants most frequently employed are *acetate of salumina*, *ulphate* or *acetate of iron*, and *muriate of tin*. The substance to be dyed is first impregnated with the mordant, and then passed through a solution of the colouring matter, which is thus fixed in the fibre, and its tint is either modified or exalted by the operation.

The following are the modes of producing some of the principal colours:

Black. 1611. *Black* is produced by astringents and salts of iron, and if intended to be deep and perfect, the cloth should previously be dyed blue with indigo. The stuff is first soaked in a bath of galls, then rinced, and passed repeatedly through a solution of sulphate of iron in infusion of logwood; exposure to air deepens the colour, which at first has a purplish tint. Logwood tends considerably to improve the black, and prevents its acquiring a rusty or brown hue. Sometimes madder is used for the same purpose. Silk is dyed black nearly in the same way, but it requires a much larger relative proportion of galls, and the operation must be frequently repeated. It is difficult to give a good and permanent black to calico; in this process, acetate of iron, galls, and madder are generally used, and the colour is rendered more durable by previously steeping the goods in a weak solution of glue.

Grey. *Grey* is produced by the same operations as black, but the materials are used in a very dilute state.

Blue. 1612. *Blue* is chiefly derived from *indigo*, a substance produced by fermenting the leaves of several species of the *indigofera*, a plant abundantly cultivated in South America and in the East Indies.

Indigo. 1613. *Indigo* is a substance of a deep blue colour, containing about 50 *per cent.* of pure colouring matter, which is perfectly insoluble in water; when heated it sublimes in the form of a blue smoke, which on condensation, forms acicular crystals. It is soluble in concentrated sulphuric acid. This solution is usually called *Saxon* or *liquid blue*, and is used as a substantive colour for dyeing cloth and silk. Substances which powerfully attract oxygen render indigo green, and by exposure to air, it again acquires a blue colour. In this green state indigo is soluble in the alcalis, and the solution is commonly employed for dyeing calico. A bath for this purpose may be made by mixing one part of indigo, two parts of sulphate of iron, and two of lime, in a sufficient quantity of water: in this case the sulphate of iron is decomposed by a portion of the lime. The protoxide of iron thus produced becomes peroxidized at the expense of the indigo, which is rendered green and soluble in the alcaline liquor; cotton steeped in this solution acquires a green colour, which by exposure to air, and washing in water acidulated with sulphuric acid, becomes a permanent blue.

A little iron or zinc thrown into diluted sulphate of indigo, changes or destroys the colour in consequence of the evolution of hydrogen; the colour is also quickly impaired and destroyed by chlorine.

1614. The analysis of indigo, to ascertain the proportion of colouring matter, which varies much in different samples, may be performed by the successive action of water, alcohol, and muriatic acid (CHEVREUL, *Ann. de Chim.* lxvi. 20.) 100 parts of Guatimala indigo, thus treated, afforded

To Water	Green matter combined with ammonia	12
	Deoxidized indigo	
	Extract	
	Gum	
To Alcohol	Green matter	30
	Resin	
	A trace of indigo	
To Muriatic Acid	Red resin	6
	Carbonate of lime	2
	Oxide of Iron	2
	Alumina	
Residue	Silica	3
	Pure indigo	45
		100

1615. The action of nitric acid on indigo has been particularly examined by Mr. HATCHETT (*Additional Experiments on Artificial Tannin, Phil. Trans.* 1805.) This acid, diluted with about two parts of water, produces much effervescence when poured on powdered indigo, and gradually dissolves it; the solution, evaporated to dryness, leaves a yellow residue, soluble in water, of an intensely bitter taste, and composed partly of artificial Tannin, and partly of a peculiar *bitter principle* combined with ammonia.

Yellow.

1616. *Yellow.* There are several dye stuffs employed in the production of yellows. A decoction of *Weld* (*Reseda Luteola,*) with an aluminous mordant gives a good yellow, which is rendered more brilliant by tartar, and by permuriate of tin.

The bark of the American oak (*Quercus Nigra,*) or *Quercitron bark*, also furnishes excellent yellows; it was first introduced into England by Dr. Bancroft, who has fully and philosophically detailed its various applications (*Experimental Researches concerning the Philosophy of Permanent Colours*, &c., London, 1813.) The salts of alumina and of tin are the principal mordants employed both with wool and cotton.

Fustic wood, sumach, and *dyers' broom*, are also occasionally employed as sources of yellow colours.

Reds.

1617. *Reds* are chiefly produced from *madder*, the prepared root of the *Rubia Tinctorum.* The colouring matter is fixed by an aluminous mordant, assisted by galls, but the process is very complex and circuitous. In Dr. Bancroft's work above quoted (Vol. ii.) are full details upon this subject; and a perspicuous abstract of them will be found in AIKIN's *Dictionary*, Art. DYEING.

Brazil wood, safflower, and *logwood* are occasionally employed as red or pink dye stuffs, but they only give fugitive colours.

Scarlet.

1618. *Scarlet* is produced exclusively with the colouring matter of the *cochineal*, a small insect brought from Mexico, where it is found upon different species of the *Opuntia.* The nature of this colouring matter has been investigated by MM. Pelletier and Caventou; it is united in the insect with a peculiar animal matter, fat, and some saline substances; they separated it by exposing a strong alcoholic tincture of cochineal to spontaneous evaporation; it deposited a crystalline matter, which was re-dissolved in alcohol and the solution mixed with its bulk of sulphuric ether; this caused it in a few days to deposit the pure colouring principle, which they call *Carminium:* Dr. John has proposed for it the term *Coccinellin*. This substance is fusible at about 120°, very soluble in water, less so in alcohol, and insoluble in ether; the acids change its colour from purple to pale red or yellow: the alcalis render it violet; and its colour is impaired by most saline solutions. It readily combines with alumina, forming a beautiful *lake* or *carmine*.

The colouring matter of cochineal is fixed upon wool by nitromuriate of tin and tartar, by which scarlets are produced, and alum changes the scarlet to crimson. Cotton and linen are very rarely dyed with cochineal, for independent of its great expense the colours are little superior to those given by madder.

Buff. 1619. *Buff* and *Fawn Colour* are produced in a variety of ways. *Walnut-husks* and *Sumack*, with alum mordants, give durable colours of this description, which are rendered *Drab*, or *Grey*, by a very little iron.

Green. 1620. *Green* is obtained on woollen cloth, by passing it through the green indigo vat, and then dyeing it as for simple yellows, the relative proportion of the blue and yellow being adjusted to the intended intensity of the green. Silk is first dyed yellow, and afterwards blued with indigo. *Saxon green* is done by dyeing yellow upon a Saxon blue ground. A solution of verdigris in vinegar is sometimes used to produce a delicate green: pearlash is added before it is used, and the cotton previously impregnated with the alum mordant, is then passed through the mixture.

Besides the above, an infinite variety of *compound colours* are formed, by mixtures of the simpler tints, and of the mordants; but as my object is merely to give a general idea of the principles of the art of dyeing, I must refer the reader for practical details to the works expressly upon the subject, and more especially to Dr. Bancroft's *Treatise* already quoted.

Calico-printing. 1621. *Calico-printing* is a more refined and difficult branch of the art of dyeing. In this process adjective colours are almost always employed. The mordants, the principal of which are acetate of alumina, and acetate of iron, are first applied to the calico by means of wooden blocks or copper plates, upon which the requisite patterns are engraved. The stuff is then passed through the colouring bath, and afterwards exposed on the bleaching ground, or washed. The colour flies from those parts which have not received the mordant, and is permanently retained on those parts only to which the basis has been applied: variety of colours is produced by employing various mordants, and different colouring materials.

White spots upon a dark ground are sometimes produced by covering the parts with wax, pipe-clay, or other materials, which prevent the contact of the colour; or citric acid, thickened with gum, is applied like a mordant with the block or plate, which prevents the retention of the colour. Sometimes the colour is discharged in places by the application of chlorine.

SECTION X. *Wax.*

Extraction.

1622. THIS principle exists in many plants; it may be obtained by bruising and boiling them in water: the wax separates and concretes on cooling.

The berries of the *Myrica cerifera*, and the leaves and stem of the *Ceroxylon* afford considerable quantities of wax by this process (BOSTOCK, NICHOLSON'S *Journal*, Vol. iv., BRANDE, *Phil. Trans.* 1811.) The glossy varnish upon the upper surface of the leaves of many trees is of a similar nature, and though there are shades of difference, these varieties of wax possess the essential properties of that formed by the bee.

Properties.

Cerates.

1623. Pure wax is colourless and insipid; its specific gravity is about .96: it is insoluble in water, and fusible at a temperature of about 150°; at a higher temperature it is converted into vapour, and at a red heat it burns in the contact of air with a bright flame. It is sparingly soluble in boiling alcohol and ether, and is deposited as the solutions cool. The fixed oils, when assisted by heat, readily dissolve it, and form a compound of variable consistency, which is the basis of *cerates* and *ointments*. Some of the volatile oils also dissolve wax, when aided by heat. It is soluble in the fixed alcalis, forming soapy compounds; but the acids scarcely act upon it; hence the advantage of *wax-lute*, for the retention of corrosive vapours.

Cerin.

Myricin.

1624. When bees'-wax, or myrtle-wax, are digested in boiling alcohol, they afford, according to Dr. John, a soluble and insoluble portion; he has called the former *cerin*, the latter *myricin*. Cerin is insoluble in water and in cold alcohol and ether, but dissolves in those liquids when heated. Myricin is insoluble, under all circumstances, in alcohol and ether.

The term *cerine* has been applied by Chevreul to a principle resembling wax, which he separated from cork; it is less fusible than wax, more soluble in alcohol, and partly converted into oxalic acid, by the action of nitric acid (1598).

1625. According to Gay-Lussac and Thenard, 100 parts of wax consist of 81.79 carbon, 6.30 of the elements of water, and 11.91 of excess of hydrogen; these numbers may be considered as equivalent to

1	Proportional of	oxygen	. . . . . . =	8 . .	5.48
20	,, ,,	carbon	6 × 20 =	120 . .	82.2
18	,, ,,	hydrogen	1 × 18 =	18 . . .	12.32
				146	100.00

* * *

SECTION XI. *Fixed Oil.*

Extraction.

1626. FIXED OIL is generally obtained by pressure from certain seeds, such as the almond, linseed, and many others, and from the olive. The specific gravity of the fixed oils, is usually a little below that of water. They are viscid; insipid, or nearly so; and generally congeal at a temperature not so low as that required to freeze water. A few of them are solid at the ordinary temperature, and have been called *vegetable butters*. They are insoluble in water, but by the aid of mucilage may be diffused through it, forming *emulsions*. They are for the most part sparingly soluble in alcohol and ether, though castor-oil dissolves in any quantity in those fluids.—Brande, *Phil. Trans.* 1811.

1627. Olive oil is sometimes adulterated with that of certain seeds, which may be detected by the action of nitrate of mercury. For this purpose, 6 parts of mercury are dissolved without heat in 7.5 parts of nitric acid, specific gravity 1.36; this solution, shaken with olive oil, becomes solid in a few hours; but if sophisticated with oil of grains, it does not solidify it.

1628. If oil, which has been congealed by cold, be submitted to pressure between folds of bibulous paper, a dry, concrete, fatty matter is obtained, which Chevreul has called *Stearine*: the paper absorbs a fluid matter, which does not congeal at a much lower temperature, and which,, though it does not become rancid, acquires viscidity by exposure to air. This fluid part he has called *Elaine*. The relative proportions of these principles differ in the different oils.—*Annales de Chimie*, Tom. xciii. xciv.—See *Animal Oils*.

Stearine.

Elaine.

1629. These oils cannot be volatilized without decomposition, which takes place at a temperature of about 600°, and water is copiously formed, attended by the separation of carbonaceous matter, which causes the oil to blacken and grow thick; a portion of acetic acid is also at the same time formed. If the vapour be collected it is found acrid, sour, and empyreumatic; it was formerly employed in pharmacy, under the name of *philosophers' oil*, and as it was often obtained by steeping a brick in oil, and submitting it to distillation, it was also called *oil of bricks*. Passed through a red-hot tube, the fixed oils furnish a very large proportion of carburetted hydrogen gas (435); and when burned in the wicks of lamps they suffer a similar decomposition, and water and carbonic acid are the products of their combustion.

Oil of bricks.

1630. The greater number of the fixed oils undergo little other change by exposure to air than that of becoming somewhat more viscid, and acquiring a degree of rancidity. In this state they contain free acid, and redden vegetable blues. Some few, such as linseed and nut-oil, and the oils of the poppy and hempseed, become covered with a pellicle, and when thinly spread upon a surface, instead of remaining greasy, become hard and resinous; these are termed *drying oils*, and their drying quality is much improved by boiling them upon a small quantity of litharge.

Drying oils.

1631. The drying oils, and especially nut-oil, form the basis of *printers' ink*, the history of which will be found in Lewis's *Phil. Commerce of the Arts*. The oil is heated and set fire to, and after having been suffered to burn for half an hour is extinguished, and boiled till it acquires a due consistency; in this state it is called *Varnish*, and is viscid, tenacious, and easily miscible with fresh oil, or with oil of turpentine, by which it is properly thinned, and afterwards mixed with about one-eighth part of lamp-black.

Action of alcalis.

1632. The alcalis readily combine with the fixed oils, and form white compounds called *Soap*. Of these the most important is the *soap of soda*, which is thus made: Five parts of barilla are mixed with one of lime and a proper quantity of water In this way a *ley*, or solution of caustic soda, is obtained, which is boiled in an iron pot with six parts of oil till the soap separates, which is accelerated by the addition of common salt; it is then suffered more perfectly to congeal, and in a few days becomes hard enough to cut into forms (AIKIN's *Dictionary*, Art. SOAP). The best soaps are made with olive oil and soda; **Soap.** in this country animal fat is usually employed for the common soaps, to which resin and some other substances are occasionally added. *Soft Soap* is a compound of potassa with some of the common oils; even fish oil is often used.

Soap furnishes a milky solution with water. It dissolves in alcohol, and the solution, if concentrated, is of a gelatinous consistency. By carefully distilling off the alcohol, a *transparent soap* is obtained.

The acids and the greater number of salts decompose soap, forming in most cases a compound of difficult solubility; hence *hard waters* are unfit for washing, in consequence of containing sulphate of lime; hence also the alcoholic solution of soap is useful as a test for ascertaining the fitness of water for this purpose, which, if it becomes very turbid, cannot in general be used for washing.

When soaps are decomposed by the acids, the oil which they contain is found to have undergone a change, the history of which will be noticed under the head of *animal oils*.

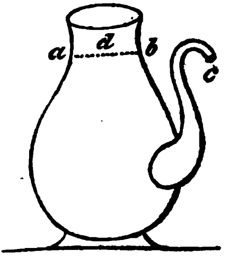
1633. The fixed oils readily combine with oxide of lead, when aided by heat, forming the compound usually termed *plaster;* with the **Plasters.** oxides of mercury and bismuth they produce very similar combinations, and are also capable of dissolving white arsenic in large proportion.

1634. The ultimate components of olive oil, as given by Gay-Lussac and Thenard, are

77.21	carbon.
9.43	oxygen.
13.36	hydrogen.
100.	

SECTION XII. *Volatile Oils.*

1635. THESE oils are generally obtained by distilling the plants **Extraction.** which afford them with water in common stills; the water and oil pass over together, and are collected in the *Italian recipient* shown in the following cut, in which the water having reached the level *a b*, runs off by the pipe *c*, and the oil being generally lighter than water, floats upon its surface in the space *d*. The whole contents of the recipient are then poured into a funnel, the tube of which is closed with the finger, and when the oil has collected upon the surface, the water is suffered to run from it, and the oil transferred into a bottle. The distilled water being saturated with the oil, should be retained for a repetition of the distillation. The produce of oil is sometimes increased, by adding salt to the water in the still, so as to elevate its boiling point a few degrees.



Some of the volatile oils are obtained by expression, such as those of *lemon orange*, and *Bergamot*, which are contained in distinct vesicles in the rind of those fruits.

1636. The volatile oils vary considerably in specific gravity, as shown by the following Table:

Oil of	Sassafras	1.094
,,	Cinnamon	1.035
,,	Cloves	1.034
,,	Fennel	997
,,	Dill	994
,,	Penny-royal	978
,,	Cummin	975
,,	Mint	975
,,	Nutmegs	948
,,	Tansy	946
,,	Caraway	940
,,	Origanum	940
,,	Spike	936
,,	Rosemary	934
,,	Juniper	911
,,	Oranges	888
,,	Turpentine	792

Properties.

1637. The volatile oils have a penetrating odour and taste, and are generally of a yellowish colour; they are for the most part very soluble in alcohol, and very sparingly soluble in water; these solutions constitute *perfumed essences* and *distilled waters*. The latter are principally employed in pharmacy, and the former as perfumes.

When pure they pass into vapour at a temperature somewhat above that of 212°, but when distilled with water, they pass over at its boiling point. They are very inflammable, and water and carbonic acid are the results of their perfect combustion. As many of these oils bear a very high price, they are not unfrequently adulterated with alcohol and fixed oils. The former addition is rendered evident by the action of water; the latter by the greasy spot which they leave on paper, and which does not evaporate when gently heated.

Action of oxygen. Chlorine.

1638. The volatile oils absorb oxygen, when long exposed to it, and become thick and resinous. They also absorb chlorine. Nitric and sulphuric acids rapidly decompose the volatile oils: a mixture of four parts of nitric, and one of sulphuric acid, poured into a small quantity of oil of turpentine, produces instant inflammation, and muriatic acid is produced, along with a peculiar substance, in some cases not unlike camphor. Iodine produces changes somewhat analogous. Muriatic acid combines with several of them, and forms a crystallizable compound which has been compared to camphor (1647).

1639. The relative quantity of essential oils, furnished from different materials, is liable to much variation; the following are the products of 1 cwt. of the different vegetable substances:

	Ounces.
Juniper-berries (common)	4 to 5
Ditto (fine Italian)	7 to 8
Aniseed (common)	32 to 36
Ditto (finest)	36 to 38

		lbs.	oz.		lbs.	oz.
Caraways	from	3	12	to	4	12
Dill-seed	from	2		to	2	6
Cloves	from	18		to	20	
Pimento	from	2		to	3	4
Fennel-seed					2	
Leaves of the *Juniperus Sabina*						14

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SECTION XIII. *Camphor.*

Soluble in alcohol.

1640. THIS substance in many respects resembles the essential oils; like them it is volatile, inflammable, soluble in alcohol, and sparingly soluble in water.

Specific gravity.

Action of oils.

In its ordinary state it is white, semi-transparent, and concrete. Its specific gravity .98. It fuses at about 300°, in close vessels. It dissolves in the fixed and volatile oils. It is scarcely acted upon by the alcalis; some of the acids dissolve, others decompose it.—HATCHETT, *Phil. Trans.* 1805. CHEVREUL, *Annales de Chimie*, lxxiii.

If mixed with bole or powdered clay, and repeatedly distilled, it is almost entirely converted into a liquid, having the characters of essential oil.

Extraction.

The camphor of commerce is obtained from the *Laurus Camphora*, and comes chiefly from Japan. It is originally separated by distillation, and subsequently purified in Europe in a subliming vessel somewhat of the shape of a turnip, from which the cakes of camphor derive their form.

Action of nitric acid.

1641. When camphor is repeatedly distilled with nitric acid it is converted into *camphoric acid*. For this purpose four ounces of camphor, reduced to powder by triturating it with a few drops of spirit of wine, may be introduced into a two-quart tubulated retort, placed in a sand heat: pour upon it 30 ounces of common nitric acid, and proceed to slow distillation. When two thirds of the acid have passed over, return it into the retort and distil as before, repeating the operation twice more; after which, as the liquor cools, a quantity of crystals of camphoric acid are deposited, which are to be washed and dried. This acid assumes the form of plumose crystals, soluble in about 100 parts of water at 60°, and in rather more than one part of alcohol. Its taste is acid, and somewhat acrid, and it has an aromatic odour. Exposed to heat it sublimes unaltered. It combines with the salifiable bases, constituting a class of salt called *Camphorates*.

1642. *Camphorate of ammonia* is with difficulty crystallized; it is sparingly soluble in water, but more copiously in alcohol.

1643. *Camphorate of Potassa* forms hexagonal crystals, soluble in about 100 parts of water at 60°, and in 25 parts at 212°. Its alcoholic solution burns with a blue flame.

1644. *Camphorate of Soda* is possessed nearly of the same properties as the preceding.

1645. *Camphorate of Lime* is nearly insoluble in water and alcohol.

1646. *Camphorate of Baryta* forms difficultly soluble lamellar crystals.—BOUILLON LAGRANGE, *Annales de Chimie*, xxvii.

Artificial camphor.

1647. When a current of muriatic acid gas is passed through oil of turpentine, it deposits a concrete substance, which has been called *artificial camphor*, and the weight of which amounts to about one-half of the oil employed. When purified by sublimation with a little quicklime, it is rendered pure and white. It is lighter than water, sublimes without decomposition, burns like camphor, and in smell resembles a mixture of camphor and turpentine (THENARD, *Mémoires d'Arcueil.* Tom. ii.) By the action of zinc it affords chloride of zinc, and the oil is evolved little altered.

Action of sulphuric acid.

1648. Camphor dissolves in sulphuric acid, forming a brown solution, from which it is at first precipitated, unaltered, by water. Sulphurous acid is afterwards evolved, the solution becomes black and thick, and, after some days, affords a brown coagulum on the addition of water, and smells fragrant and peculiar. On distilling the diluted liquor, water and a yellow oil pass over, a little sulphurous acid is then disengaged, and a black matter remains in the retort, which, when digested in alcohol, affords a portion of soluble matter having some of the properties of artificial tannin.—HATCHETT, *Phil. Trans.* 1805.

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SECTION XIV. *Resins.*

Properties.

1649. RESINS are substances which exude from many trees, either from natural fissures or artificial wounds. Common *resin is obtained* by distilling the exudation of different species of fir; *oil of turpentine* passes over, and the resin remains behind. It may be taken as a perfect example of resin, and is possessed of the following properties: It is solid, brittle, a little heavier than water, and acquires negative electricity when rubbed. It has scarcely any taste or smell; is insoluble in water; readily soluble in alcohol, which takes up about one-third its weight, and becomes milky upon the addition of water. Resin is soluble in the caustic alcalis, the solution is saponaceous, and when mixed with an acid, the resin separates, scarcely altered in its properties. Nitric, muriatic, and acetic acids dissolve it without much change*.

Balsams.

1650. A few of the resins derive odour from containing essential oil; some afford benzoic acid when heated, and these have been termed *balsams; copal, mastich*, and a few others, are very difficultly soluble in alcohol, and contain a substance somewhat analogous to caoutchouc. *Guaiacum* is characterized by the singular changes of colour, which its alcoholic solution suffers when exposed to the action of nitric acid.—*Phil. Trans.* 1811.

Guaiacum is also rendered blue by the gluten of wheat, but its colour is not changed by starch; the intensity of the blue colour is said to be proportional to the quantity of gluten present in flour.—TADDEI, *Giornale de Fisica*, i. 168. *Quarterly Journal*, viii. 376.

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* The properties of the resins have been very ably investigated by Mr. Hatchett, the details of whose researches will be found in his communications to the Royal Society, printed in the *Philosophical Transactions* for 1804, 1805, 1806.

1651. *Lac* is a substance formed by an insect, and deposited on different species of trees chiefly in the East Indies. The various kinds of lac distinguished in commerce, are *stick lac*, which is the substance in its natural state, investing the small twigs of the tree: *seed-lac*, which is the same broken off; and which, when melted, is called *shell-lac*. These substances have been examined by Mr. Hatchett*. The following table exhibits their component parts.—*Phil. Trans.* 1804.

	Stick-Lac.	Seed-Lac.	Shell-Lac.
Resin	68	88.5	90.9
Colouring matter	10	2.5	0.5
Wax	6	4.5	4.0
Gluten	5.5	2.0	2.8
Foreign bodies	6.5	—	—
Loss	4.0	2.5	1.8
	100	100	100

1652. Dr. John has announced the presence of a peculiar acid in stick-lac, which he has called *Laccic Acid*. The lac was digested in water, the solution evaporated, and the residue digested in alcohol; the alcoholic solution was evaporated to dryness, and its residue digested in ether. The evaporation of the etheric solution leaves a yellow matter, which, being again dissolved in alcohol, and the solution mixed with water, deposits a little resin, and leaves laccic acid in solution, which, upon the addition of acetate of lead, gives a precipitate of *laccate of lead;* the latter compound, by cautious decomposition by sulphuric acid, affords the laccic acid. Laccic Acid.

1653. Laccic acid is crystallizable, of a yellow colour, a sour taste, and soluble in water, alcohol, and ether. With potassa, soda, and lime, it forms deliquescent soluble salts; with lead and mercury it produces white insoluble compounds; it occasions no precipitate in the nitrates of baryta and silver.—Thomson's *System*, ii. 177. Properties.

1654. *Gum Resins* are natural combinations of gum and resin, they are consequently only partially soluble in water and in alcohol; they readily dissolve in alcaline solutions when assisted by heat; and the acids act upon them nearly as upon the resins. *Ammoniacum, gamboge, assafœtida*, and *olibanum*, may be taken as examples of gum resins.

1655. *Amber* is a substance which, in some of its properties, resembles resin; it is however, very sparingly soluble in alcohol, and difficultly soluble in the alcalis. When submitted to distillation, it furnishes an acid sublimate, which has received the name of *succinic acid*, and which, when purified by repeated solutions and crystallization, possesses the following properties:—

1656. It forms yellowish prismatic crystals soluble in 24 parts of water at 60°, and of a slightly acid and nauseous taste; it is fusible and volatile when heated. 10 lbs. of amber yield about 3 ounces of purified succinic acid. Along with the succinic acid there distils over a quantity of volatile oil, of a light brown colour, used in pharmacy under the name of *Oil of Amber*, and amounting to about one-third in weight of the amber used.

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* Dr. Pearson obtained a peculiar acid from a substance called *white lac*, from Madras. He has called it *laccic acid*.—*Phil. Trans.* 1794.

1657. *Succinate of Ammonia* forms acicular crystals, which sublime when cautiously heated. Its solution has been used as a test for iron, the peroxide of which it throws down from its neutral solutions in the form of a reddish brown precipitate.

1658. *Succinate of Potassa* is a very soluble deliquescent salt, crystallizable with difficulty in small prisms.

1659. *Succinate of Soda* forms transparent four and six-sided prisms, considerably less soluble than the preceding, and permanent in the air.

1660. *Succinate of Lime* forms permanent and difficulty soluble crystals.

1661. *Succinate of Baryta* is formed by adding succinate of ammonia to muriate of baryta. A portion is thrown down in a pulverulent form, and a part in small crystalline grains.—BERGMAN.

1662. *Succinate of Strontia* may be formed as the preceding, and presents similar properties. It burns with a fine red flame.

1663. *Succinate of Magnesia* is deliquescent and uncrystallizable.

1664. *Succinate of Manganese* has been examined by Dr. John (GEHLEN'S *Journal*, iv.) It is crystallizable, and of a slight red tinge; it consists of 30.27 protoxide of manganese + 69.73 acid and water. The theoretical constitution of succinate of manganese is

50 acid
36 oxide.

so that the above salt is probably a bi-succinate.

1665. *Succinate of Iron.* The *protosuccinate* is crystallizable and soluble; the *persuccinate* is insoluble, and is thrown *down in the form* of a brownish red flaky precipitate from solutions *of the peroxide of* iron. This salt has been proposed as a means of separating iron in analysis, but is quite inapplicable in the greater number of cases.

1666. *Succinate of Zinc* furnishes long slender crystals, which have not been examined.

1667. *Succinate of Tin.* The succinic acid dissolves protoxide of tin, and forms with it thin broad transparent crystals.

1668. *Succinate of Copper.* There appear to be two varieties of this salt, a super-succinate and a sub-succinate. (For details respecting several of the succinates, the reader is referred to WENZEL'S *Lehre der Verwandtschaft der Korper*; and to GREN, *Handbuch*, iii. 19.)

1669. *Succinate of Lead.* When succinic acid, or succinate of ammonia, is added to acetate of lead, a white precipitate of succinate of lead falls, composed, according to Berzelius, of

Succinic acid	30.9
Protoxide of lead	69.1
	100.

These numbers give 50 as the representative of succinic acid, and considering the succinate of lead as composed of 1 proportional of each of its components, it will consist of

Succinic acid	50
Protoxide of lead	112
	162

The remaining succinates are not of sufficient importance to require enumeration.

1670. The resins are applied to a variety of useful purposes; and dissolved in alcohol and oils they constitute the different *varnishes.*

Section XV. *Narcotic Principles.*

1671. The substance to which the narcotic power of opium is referable, has been examined with much attention by M. Serteurner; he has termed it *morphia.*

Extraction. Morphia may be obtained from powdered opium by triturating it into a paste with dilute acetic acid: pour caustic ammonia into the filtered solution, and evaporate; during the evaporation a brownish substance separates, which, by digestion in a small quantity of cold alcohol, becomes nearly colourless, and is pure morphia.

Morphia is sparingly soluble in water, but readily soluble in alcohol and in ether, from which it may be obtained in quadrangular and octoëdral crystals. It is highly poisonous and narcotic, even when administered in very small doses; it is fusible and combustible.

Morphia appears in some respects to possess the properties of an alcali; it reddens turmeric, and forms crystallizable compounds with the acids.

1672. *Nitrate of Morphia* forms acicular crystals, soluble in 1.5 of water, at 60°.

1673. *Sulphate of Morphia* crystallizes in prisms, soluble in two parts of water, at 60°, and composed, according to Pelletier and Caventou (*Journal de Pharmacie*, v.) of

11	Sulphuric acid.
89	Morphia.
100	

1674. *Carbonate of Morphia* forms prismatic crystals, soluble in 4 parts of water, at 60°, and containing, according to Choulant (*Annals of Phil.* xiii.)

28	Carbonic acid.
22	Morphia.
50	Water.
100	

These salts have a bitter taste, and are decomposed by ammonia; they have, however, been but imperfectly examined.

1675. In opium morphia is said to be combined with a peculiar acid, which has been called the *meconic acid*, and this combination is decomposed by the action of ammonia in the preparation of morphia.

Meconic acid. The following process is said to afford pure meconic acid: Boil infusion of opium with magnesia, and digest the precipitate in alcohol; *meconiate of magnesia* remains: dissolve this in dilute sulphuric acid, and add muriate of baryta, a precipitate falls, composed of sulphate and *meconiate of baryta;* digest this in dilute sulphuric acid, which decomposes the meconiate: filter and evaporate, till brown crystals of impure meconic acid are deposited; dry these crystals, and then heat them carefully in a retort, to sublime the meconic acid. White crystals are thus obtained, which fuse at 250°, and sublime without decomposition; they are sour, and very soluble in water and alcohol.

1676. *Meconiate of Ammonia* forms stellated crystals, soluble in 1.5 parts of water, at 60°, and composed, according to Choulant, of

42	Ammonia.
40	Meconic acid.
18	Water.
100	

1677. *Meconiate of Potassa* forms four-sided tables, soluble in 2 parts of water at 60°, and composed of

60	Potassa.
27	Meconic acid.
13	Water.
100	

1678. *Meconiate of Soda* forms efflorescent prismatic crystals, soluble in 5 parts of water at 60°, and composed of

40	Soda.
32	Meconic acid.
28	Water.
100	

1679. *Meconiate of Lime* affords prismatic crystals, soluble in 8 parts of water at 60°, and consisting of

42	Lime.
34	Acid.
24	Water.
100	

The equivalent number of meconic acid, deduced from the mean of the above analyses, by Choulant, will be about 23.

Strychnine.

1680. MM. Pelletier and Caventou, in analyzing the *bean of St. Ignatius* (*Strychnos Ignatia*), and the *vomica nut* (*Strychnos nux vomica*), discovered in them a peculiar principle, which they have termed *Strychnine*, and which, like morphia, possesses alcaline properties. The following is their process for obtaining it: Digest the raspings of the bean in sulphuric ether, which separates a green oily fluid; pour this off, and treat the residuum with alcohol; filter the latter solution when cold, and evaporate; it leaves a brown bitter substance, soluble in water and alcohol; to its strong aqueous solution add a solution of potassa, which causes a precipitate, which, when washed with a little cold water, is white, crystalline, and very bitter. If not quite pure, it may be rendered so by solution in acetic acid, and precipitation by potassa.

1681. Strychnine, or *Strychnia*, is nearly insoluble in water; it dissolves in alcohol, and the solutions are intensely bitter and poisonous. It reproduces the blue of vegetable colours reddened by acids. It crystallizes in small quadrangular prisms; it has no smell, and is neither fusible nor volatile, but is decomposed at about 600° into products consisting of oxygen, hydrogen, and carbon.

1682. The *Salts of Strychnia* are decomposed by potassa, soda, ammonia, baryta, strontia, and magnesia, the base being thrown down; most of the other metallic salts are decomposed by strychnia, and with some it forms triple salts.

1683. *Sulphate of Strychnia* forms cubic crystals, soluble in about 10 parts of water at 60°; its taste is bitter, and it is decomposed by the alcalis. It consists of

Sulphuric acid	9.5
Strychnia	90.5
	100.

1684. *Muriate of Strychnia* crystallizes in acicular prisms more soluble than the sulphate.

1685. *Nitrate of Strychnia* is formed by digesting excess of strychnia in very dilute nitric acid; it yields stellated crystals, which acquire a red colour by the action of sulphuric acid. Nitric acid poured upon strychnia or its salts produces a deep red colour.

1686. The discoverers of strychnia assert that it exists in the abovementioned seeds, combined with a peculiar acid, somewhat resembling the malic, but susceptible of crystallization; they have called it *Igasuric Acid*, and the poisonous principle existing in the seeds, appears to be an *igasurate of strychnia*.

1687. *Brucine*. This term has been applied to a peculiar alcaline substance, obtained from Angustura bark, by the above-named chemists. Its properties, as far as they have been investigated, are described in the *Annales de Chimie* (xii. p. 113.) and in the *Quarterly Journal of Science and the Arts* (ix. 189).

1688. *Delphine* is an alcaline principle, discovered by MM. Lassaigne and Feneulle in the seeds of stavesacre (*Delphinium Staphysagria*). They obtained it by the following process: The seeds, deprived of their husks, were boiled in distilled water, the decoction filtered, boiled with a portion of pure magnesia, and re-filtered; the residue upon the filter was then boiled with highly rectified alcohol, by which the alcali was separated and obtained by evaporation in the form of a white pulverulent substance.

Delphine, when pure, appears crystalline in its moist state; its taste is bitter and acrid; when heated, it melts, and on cooling becomes brittle like resin; it is sparingly soluble in water, but readily soluble in alcohol and ether; it renders the blue of violets green, and forms very soluble salts with the acids, from which the alcalis precipitate delphine in a white gelatinous state.—*Annales de Chimie et Phys.*, xii. 358.

SECTION XVI. *Bitumens, coal, &c.*

1689. **BITUMENS** are fossile substances, bearing considerable resemblance to oily and resinous bodies. The chemical habitudes of several of these substances have been ably investigated by Mr. Hatchett. (*Phil. Trans.*, 1804.) The following are the principal varieties :

a. Naphtha is a pungent, odoriferous, oily liquid, either colourless or of a pale brown tint, found upon the borders of the Caspian Sea, and in certain springs in Italy. It is considerably lighter than water, volatile, and highly inflammable. When pure it appears to contain no oxygen, and hence is employed for the preservation of potassium, and the other highly oxidable metals. It consists, according to Saussure, of

Carbon	87.21
Hydrogen	12.79
	100.

b. Petroleum has most of the properties of naphtha, but is less fluid, and darker coloured. In the countries where it abounds, it is employed for burning in lamps.

c. Mineral Tar appears to be petroleum further inspissated. It is more viscid, and of a deeper colour.

d. Maltha, or *Mineral Pitch*, is a soft inflammable substance, heavier than water, and may be considered as derived from the exsiccation of mineral tar.

e. Asphaltum is found abundantly on the shores of the Dead Sea, in Albania, and in the island of Trinidad. Its colour is brown or black; it is heavier than water, and readily soluble in naphtha.

f. Elastic Bitumen, or *Mineral Caoutchouc*, is found only in the vicinity of Castleton in Derbyshire. It is fusible and inflammable.

g. Mineral Adipocere is a fatty matter found in the argillaceous iron ore of Merthyr : it is fusible at about 160°, and inodorous when cold, but of a slightly bituminous odour when heated, or after fusion.

The above substances are insoluble in water, and difficultly soluble in alcohol, with the exception of naphtha and petroleum, which are soluble in highly-rectified alcohol.

h. Retinasphaltum is a substance which accompanies the Bovey Coal of Devonshire. It was first analyzed by Mr. Hatchett, who found it to consist of

55	Resin.
41	Asphaltum.
4	Earthy matter and loss.

i. Pit Coal. There are three chemical varieties of this important substance. The first, or *brown coal*, retains some remains of the vegetables from which it has originated. When heated it exhales a bituminous odour, and burns with a clear flame. It is generally of a tough consistency and yields according to Mr. Hatchett, a portion of unaltered vegetable extract, and resin.

The second variety, or *black coal*, is the ordinary fuel of this country. It exhibits no traces of vegetable origin, and consists principally of bitumen and charcoal, in variable proportions. When exposed to heat, it swells, softens, and burns with a bright flame, leaving a small quantity of ashes. Many varieties, however, abound in earthy matter, and these produce copious cinders, and burn with a less intense heat. The products of the destructive distillation of this kind of coal have been already described (431). The residue is a hard sonorous charcoal, termed *coke*, and containing the earthy ingredients of the coal.

The third variety, or *glance coal*, consists almost entirely of charcoal, and earthy matter. It burns without flame, and when distilled produces scarcely any gaseous matter.

k. Peat and *Turf* consist principally of the remains of vegetables, having undergone comparatively little change. They often contain bituminous wood, and branches and trunks of trees.

l, Mellilite, or *Honeystone*, is a rare substance, found in the brown coal of Thuringia and in Switzerland. It is of a honey yellow colour, crystallized in octoëdra, and when analyzed by Klaproth, was found to consist of alumina combined with a peculiar body which has been called the *mellitic acid*.—KLAPROTH's *Essays*, ii. 89. VAUQUELIN. *Annales de Chimie*, xxxvi. 203.

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SECTION XVII. *Vegetable Acids.*

1690. THE following are the principal acids, which are found ready formed in vegetable products :

1. Tartaric acid.	4. Malic acid.
2. Oxalic acid.	5. Gallic acid.
3. Citric acid.	6. Benzoic acid.

i. TARTARIC ACID.

1691. THIS acid exists in several vegetable substances ; it is one of the sour principles of many fruits, and is said to be abundant in the potatoe-apple. Tartaric acid is generally obtained from the *bi-tartrate of potassa*. Mix 100 parts of this salt in fine powder with 30 of powdered chalk, and gradually throw the mixture into 10 times its weight of boiling water : when the liquor has cooled, pour the whole upon a linen strainer, and wash the white powder which remains with cold water : this is a *tartrate of lime ;* diffuse it through a sufficient quantity of water, add sulphuric acid equal in weight to the chalk employed, and occasionally stir the mixture during 24 hours ; then filter, and carefully evaporate the liquor to about one-fourth its original bulk ; filter again, and evaporate with much care nearly to dryness ; re-dissolve the dry mass in about 6 times its weight of water, render it clear by filtration, evaporate slowly to the consistency of syrup, and set aside to crystallize. By two or three successive solutions and crystallizations, tartaric acid will be obtained in colourless crystals, soluble in 6 parts of water at 60°. According to Berzelius, the crystals contain

Mode of obtaining.

11.25 per cent. of water. The aqueous solution of tartaric, in common with the other vegetable acids, soon becomes mouldy, and suffers decomposition.

1692. When tartaric acid is submitted to destructive distillation, it affords a brown acid liquor which has been termed *pyrotartarous acid.*

1693. According to Berzelius, the *tartrate of lead*, which is an insoluble salt, and easily formed by adding tartaric acid to a solution of nitrate of lead, consists of

Tartaric acid	100
Oxide of lead	167

And regarding this salt as composed of 1 proportional of acid and 1 of oxide, we obtain the number 67.0 as the representative of tartaric acid, for

$$167 : 100 :: 112 : 67.0$$

1694. Tartaric acid combines with the metallic oxides, and produces a class of salts called *tartrates*, the composition of which will be obvious from the preceding datum.

1695. *Tartrate of ammonia* forms very soluble prismatic crystals, of a cooling taste. The addition of tartaric acid to its aqueous solution produces a precipitate of a difficultly soluble *bi-tartrate* of ammonia.

1696. *Tartrate of Potassa* is formed by saturating the excess of acid in *tartar*, by potassa. According to Mr. Richard Phillips (*Remarks on the Pharmacopœia,*) 100 parts of tartar require 43.5 of carbonate of potassa. The resulting salt is soluble in less than twice its weight of water; it crystallizes in four-sided prisms, and consists of

1 proportional acid. . . . . . . = 67.
1 . . . . potassa . . . . . = 48.

Tartrate of potassa . . . . . = 115.

This salt is used in pharmacy as an aperient; it is the *potassæ tartras* of the *Pharmacopœia.* Its taste is saline, and somewhat bitter.

1697. *Bitartrate*, or *Supertartrate of potassa. Tartar.* This substance exists in considerable abundance in the juice of the grape, and is deposited in wine casks, in the form of a crystallized incrustation, called *argol*, or *crude tartar.* It is purified by solution and crystallization, which renders it perfectly white: when in fine powder it is termed *cream of tartar.*

Tartaric acid test for potassa.

It may also be formed by adding excess of tartaric acid to a solution of potassa. The mixture presently deposits crystalline grains, and furnishes a striking example of the diminution of solubility by increase of acid in the salt. Upon this circumstance the use of tartaric acid as a test for potassa depends, for soda forms an easily soluble supertartrate and consequently affords no precipitate. (578)

Bi-tartrate of potassa is composed of

2 proportionals of acid. . = 134
1 proportional of potassa = 48

Bi-tartrate of potassa = 182

This salt requires 120 parts of water at 60°, and 30 parts at 212° for its solution.

When exposed to heat, tartar fuses, blackens, and is decomposed: and carbonate of potassa is the remaining result (569). Provided the tartar be free from lime, which however is seldom the case, this furnishes a good process for obtaining pure carbonate of potassa. The aqueous solution of tartar becomes mouldy when exposed to air, and the tartaric acid being entirely decomposed leaves a weak solution of carbonate of potassa.

The component parts of tartar render it an excellent flux in the reduction of metallic ores upon a small scale, its alcali promoting their fusion, and the carbonaceous matter tending to reduce the oxides. Flux.

1698. *Tartrate of Potassa and Ammonia* is formed by saturating the excess of acid in tartar with ammonia. It effloresces and loses ammonia by exposure to air.

1799. *Tartrate of Soda* forms acicular crystals soluble in their own weight of water. Tartaric acid, added to their solution, forms a *supertartrate of soda*, much more soluble than the corresponding salt of potassa.

1700. *Tartrate of Potassa and Soda* is prepared by saturating the excess of acid in tartar, with carbonate of soda; it is the *soda tartarizata* of the *Pharmacopœia;* it forms irregular prismatic crystals. It has long been used in pharmacy under the name of *Rochelle Salt* and *Sel de Seignette.* According to Vauquelin's analysis (FOURCROY's *Connaissances*, vii. 240.) this salt consists of 54 tartrate of potassa + 46 tartrate of soda *per cent.:* these numbers agree with

2 proportionals of acid . . = 134
1 ———————— potassa = 48
1 ———————— soda . . = 32
214

1701. *Tartrate of Lime* is nearly insoluble in cold water, but soluble in 600 parts of boiling water; it is produced by adding chalk to tartar, as in the process for obtaining tartaric acid, where it is decomposed by sulphuric acid.

1702. *Tartrate of Potassa and Lime* may be formed by adding limewater to solution of supertartrate of potassa, till it begins to become turbid: in a few days acicular crystals of the above triple salt are deposited, which effloresce when exposed to air.

1703. *Tartrate of Baryta* is a difficultly soluble salt.

1704. *Tartrate of Strontia* is thrown down on mixing the solutions of tartrate of potassa and nitrate of strontia. It dissolves in rather more than 300 parts of boiling water, and forms small crystals as the solution cools.

1705. *Tartrate of Magnesia* is precipitated from the sulphate by tartaric acid: it is soluble in excess of tartaric acid, and forms a crystallizable salt.

1706. *Tartrate of Manganese*, formed by dissolving protoxide of manganese in tartaric acid, is a soluble salt, and therefore not produced by adding tartaric acid or a neutral tartrate to protomuriate or protosulphate of manganese.

1707. *Tartrate of Iron.* Both the tartrates of iron are easily soluble, and no precipitate is formed by tartaric acid, or by tartrate of potassa, in solutions of iron.

1708. *Tartrate of Iron and Potassa.* This is the *Ferrum tártarisatum* of the *Pharmacopœia*, but it is most conveniently employed as a medicine in solution, which may be formed by digesting 1 part of soft iron filings with 4 of tartar; this mixture should be made into a thin paste with water, and digested for some weeks, till the acid is neutralized, fresh portions of water being occasionally added to prevent exsiccation. The solution of this compound, which contains the iron in the state of peroxide, is possessed of some curious properties, first pointed out by Mr. R. Phillips.—*Experimental Examination of the London Pharmacopœia*, 98.

1709. *Tartrate of Zinc* is formed by adding tartrate of potassa to sulphate of zinc, and appears to be a very difficultly soluble compound.

1710. *Tartrate of Tin.* Tartrate of potassa occasions a white precipitate in the protomuriate and permuriate of tin.

1711. *Tartrate of Potassa and Tin* is formed by boiling the oxide in solution of tartar; it is very soluble, and the addition of alcalis and their carbonates occasion no precipitates.—Thenard, *Annales de Chim.* xxxviii.

1712. *Tartrate of Copper* is produced by adding tartaric acid to sulphate of copper. It forms bluish-green crystals.

1713. *Tartrate of Potassa and Copper* is formed by boiling oxide of copper and tartar in water; the solution yields blue crystals on evaporation; or if boiled to dryness, furnishes one of the pigments called *Brunswick green.*

1714. *Tartrate of Lead* is thrown down in the form of an insoluble white powder on adding tartaric acid to solution of nitrate of lead. Its composition has already been adverted to (1693).

1715. *Tartrate of Potassa and Lead* is formed, according to Thenard, by boiling a mixture of tartar and oxide of lead in water.—*Annales de Chim.*, xxxviii.

1716. *Tartrate of Antimony* has not been examined.

1717. *Tartrate of Antimony and Potassa. Emetic Tartar.* This compound may be obtained by boiling protoxide of antimony, obtained by any of the processes formerly described (907) with pure supertartrate of potassa. It is the *antimonium tartarizatum* of the *London Pharmacopœia.*

Emetic tartar may be prepared by boiling a solution of 100 parts of tartar with 100 parts of finely levigated glass of antimony, or of the protoxide described above (907); the ebullition should be continued for half an hour, and the filtered liquor evaporated to about half its bulk, and set aside to crystallize: octoëdral and tetraëdral crystals of the emetic salt are thus obtained; and there is generally formed along with them a portion of tartrate of lime and potassa, which is deposited in small tufts of a radiated texture, and which may easily be separated when the mass is dried.

Mr. Phillips, in his *Experimental Examination of the London Pharmacopœia*, has stated several facts respecting the formation of this salt, which will be found useful to the manufacturer.

Emetic tartar is a white salt, slightly efflorescent, soluble in about 14 parts of cold and 2 parts of boiling water. It is decomposed by the alcalis, and when heated with ammonia, a portion of protoxide of antimony is thrown down, and a very soluble compound remains in the liquor. Sulphuretted hydrogen and hydrosulphuret of ammonia produce orange-coloured precipitates in its solution. It is decomposed by bitter and astringent vegetable infusions, but they do not render it inactive as a medicine. Mr. Phillips has shown that emetic tartar consists of 100 supertartrate of potassa + 66 protoxide of antimony. If we consider it, with Dr. Thomson, (*System*, ii. 670.) as a compound of 2 proportionals of tartaric acid, 2 of protoxide of antimony, and 1 of potassa; or as containing 1 proportional of tartrate of potassa and 1 of subtartrate of antimony, its components will stand thus:

$$\begin{array}{lr} \text{Tartaric acid} \ldots\ldots\ 67 \times 2 = & 134 \\ \text{Protoxide of antimony}\ .\ 56 \times 2 = & 112 \\ \text{Potassa} \ldots\ldots\ldots\ldots\ldots = & 48 \\ \hline & 294 \end{array}$$

1718. *Tartrate of Bismuth* has not been examined, but moist oxide of bismuth boiled with tartar forms a difficultly soluble triple salt.

1719. *Tartrate of Cobalt.* Tartrate of potassa forms no precipitate in solutions of cobalt, but their colour is much heightened by it.

1720. *Tartrate of Uranium* is a very soluble salt, not easily crystallizable.

1721. *Tartrate of Titanium* appears to be a soluble compound.

1722. *Tartrate of Cerium*, according to Hisinger and Berzelius, is formed by adding tartrate of potassa to sulphate, nitrate, or muriate of cerium. It is a soft tasteless powder, soluble in nitric, muriatic, and sulphuric acids, and in the alcalis.

1723. *Tartrate of Nickel*, formed by digesting moist oxide of nickel in tartaric acid, is a very soluble salt; tartaric acid occasions no precipitate in the soluble salts of nickel.

1724. *Tartrate of Mercury.* Tartaric acid occasions white precipitates in all the solutions of oxide of mercury not containing excess of acid.

1725. *Tartrate of Potassa and Mercury* is formed, according to Thenard, by adding solution of tartar to nitrate of mercury.

1726. *Tartrate of Silver.* Tartaric acid occasions no change in nitrate of silver, but tartrate of potassa forms a white precipitate, which is probably a tartrate of silver.

1727. *Tartrate of Silver and Potassa* is thrown down by adding tartar to nitrate of silver.

1728. *Tartrate of Alumina* is a soluble uncrystallizable compound of an astringent flavour.

ii. OXALIC ACID.

1729. This acid is found in some fruits, and in considerable quantity in the juice of the *Oxalis Acetosella*, or *wood-sorrel*, and in the varieties of *rhubarb*. It is most readily procured by the action of nitric acid upon sugar, and has hence been termed *acid of sugar*.

It may be obtained by introducing into a retort 4 ounces of nitric acid diluted with 2 of water and 1 ounce of white sugar; nitric oxide gas is copiously evolved, and when the sugar has dissolved, about one-third of the acid may be distilled over: the contents of the retort are then emptied into a shallow vessel, and in the course of two or three days an abundant crop of white crystals is deposited, and, upon further evaporation of the mother-liquor, a second portion is obtained. The whole crystalline produce is to be re-dissolved in water, and again crystallized, by which the pure acid is obtained. In this way sugar yields rather more than half its weight of oxalic acid.

1730. Oxalic acid thus procured is in the form of four-sided prisms, transparent, and of a very acid taste: they dissolve in two parts of water at 60°, and in their own weight at 212°. When carefully dried, they fall to powder, and lose more than one-third of their weight, being composed, according to Berzelius, (*Ann. de Chim.* lxxxi.) of

Real acid	52
Water	48
	100

1731. By repeated distillation with nitric acid, oxalic acid is resolved into carbonic acid and water; and the acid itself, and the salts containing it, as is the case with the other vegetable acids, are decomposed by heat. By distilling oxalate of lime, Dr. Thomson found the acid resolved into five new substances; namely, water, carbonic acid, carbonic oxide, carburetted hydrogen, and charcoal; and by a very elaborate analysis of these gases, he determined the composition of the acid as follows:

Oxygen	64
Carbon	32
Hydrogen	4
	100

which numbers do not quite correspond with those given by Gay-Lussac and Thenard (p. 17).

1732. The number representing the oxalic acid, founded upon Dr. Wollaston's analysis of the binoxalate of potassa, (*Phil. Trans.* 1804.) and upon Berzelius's analysis of the oxalate of lead, (*Annales de Chimie*, No. 243.) is about 37.7. According to the latter chemist, oxalate of lead consists of 100 oxalic acid + 296.6 oxide of lead, and

$$296.6 : 100 :: 112 : 37.7$$

The number deduced from the mean of the best analyses of oxalate of lime, is 37.7; and accordingly, 38 may without material error be adopted as the representative number of oxalic acid, and the composition of the oxalates will be obvious accordingly.

1733. *Oxalate of Ammonia* is a very useful test for the presence of lime. It crystallizes in long prisms, of which 45 parts require 1000 of water for their solution. Added to any soluble compound of lime this salt produces an insoluble *oxalate of lime*.

1734. *Oxalate of Potassa* forms flat rhomboidal crystals soluble in 3 parts of water at 60°. It consists of 38 acid + 48 potassa. This salt, dissolved in oxalic acid, produces the *binoxalate of potassa*, which crystallizes in four-sided prisms, and consists of 2 proportionals acid $38 \times 2 = 76 + 48$ potassa. When this binoxalate is digested in dilute nitric acid, a portion of the alcali is taken up, and a salt remains, consisting of 4 proportionals of oxalic acid 38 × 4 = 152 + 1 proportional potassa = 48. This is the *quadroxalate of potassa*, and is the salt which exists in the wood-sorrel.

1735. *Oxalate of Soda* is sparingly soluble in water, and separates from its solution in small crystalline grains.

1736. *Oxalate of Lime.* This compound is formed by adding oxalic acid or oxalate of ammonia to any solution of lime. It is insoluble in water, and in excess of oxalic acid, but dissolves in muriatic and nitric acids: hence in testing acid solutions for lime by oxalic acid, or oxalate of ammonia, the excess of acid should be previously neutralized. This oxalate consists of 38 acid + 28 lime = 66. oxalate of lime; or of

42.74	lime
57.26	acid
100.00	

Vogel's analysis gives

43.75	lime
56.25	acid
100.	

Annals of Philosophy, Vol. v. 30.

1737. The *Oxalates of Strontia, Baryta*, and *Magnesia*, are very nearly insoluble, and with most other metallic oxalates may be formed by double decomposition. They consist respectively of one proportional of each of their components.

1738. When black oxide of manganese and superoxalate of potassa are triturated together and moistened, carbonic acid is evolved; and on adding more water, and filtering, a red solution, containing oxalic acid, potassa, and deutoxide of manganese is obtained, which after a time becomes colourless, and a triple salt is formed, containing the protoxide of manganese.

1739. *Oxalate of Iron.* The *protoxalate* crystallizes in green prisms, and may be formed either by digesting the metal, or dissolving the protoxide in the acid. The *peroxalate* is thrown down from the permuriate or persulphate of iron, in the form of a difficultly soluble yellow powder, which is taken up again by excess of oxalic acid: hence the use of this acid in removing iron-moulds which it does without injuring the texture of linen.

1740. *Oxalate of Zinc* is formed by adding oxalic acid to a soluble salt of zinc: it is a white powder, nearly insoluble.

1741. *Oxalate of Tin* is formed, according to Bergman, by digesting the metal in the acid: the solution, slowly evaporated, gives prismatic crystals.

1742. *Oxalate of Copper.* Oxalic acid oxidizes and dissolves copper. When oxalic acid is added to persulphate or pernitrate of copper, a difficultly soluble *peroxalate of copper* is thrown down. The theoretical composition of this salt is 1 proportional peroxide of copper = 80. +2 of oxalic acid 76. = 156.

1743. *Oxalate of Copper and Ammonia.* This, and several other triple oxalates of copper, have been described by Vogel. (SCHWEIG-

GER'S *Journal*, vii.) By digesting peroxalate of copper in a solution of oxalate of ammonia and filtering, rhomboidal crystals were obtained on evaporation, which detonate when suddenly heated: when slowly heated they merely lose water and ammonia. From the analysis of this salt it evidently consists of 2 proportionals of oxalate of ammonia, 1 peroxalate of copper, and 6 water.

By digesting oxalate of copper in caustic ammonia, and pouring the solution thus obtained into a shallow basin, it deposits flat six-sided prisms of a blue colour, which effloresce on exposure to air. The undissolved portion of the oxalate also combines with ammonia, and produces another distinct compound. Dr. Thomson has given the following view of the composition of these salts.—*System* ii., 624.

	1st. Subspecies.	2d. Subspecies.	3d. Subspecies.
Oxalic acid	4 prop.	2	2
Ammonia	2	2	1
Peroxide of copper	1	1	1
Water	6	2	0

1744. *Oxalate of Copper and Potassa* is obtained by digesting percarbonate of copper in solution of binoxalate of potassa. Acicular and rhomboidal crystals are formed, which Vogel considers as two distinct salts.—THOMSON'S *System*, ii., 620.

1745. *Oxalate of Copper and Soda.* Vogel has also described two subspecies of this salt.—SCHWEIGGER'S *Journal*, vii.; THOMSON, ii., 621.

1746. *Oxalate of Lead* is thrown down in crystalline grains on adding oxalic acid to nitrate of lead. Its composition has already been stated (1732).

1747. *Oxalate of Antimony* has not been examined.

1748. *Oxalate of Bismuth* is deposited in crystalline grains, when solution of oxalic acid is dropped into nitrate of bismuth.

1749. *Oxalate of Cobalt* is an insoluble red powder, precipitated by oxalic acid from solutions of cobalt.

1750. *Oxalate of Uranium* is a soluble compound.

1751. *Oxalate of Nickel* is thrown down from the nitrate in the form of an insoluble green powder.

1752. *Oxalate of Mercury* is precipitated from the nitrate by oxalic acid. It is scarcely soluble, and detonates when heated.

1753. *Oxalate of Silver* is an insoluble white powder, which blackens by exposure to light. It is precipitated on adding oxalic acid to nitrate of silver, and is soluble in nitric acid.

1754. *Oxalate of Alumina* is easily formed by dissolving the newly precipitated earth in oxalic acid: it does not crystallize, but affords on evaporation a gelatinous mass, which deliquesces on exposure.

Antidote for oxalic acid.

1755. The oxalic acid swallowed in large doses is an active poison, and fatal cases are not unfrequent in which this acid is taken by mistake for Epsom salt. The instant that the accident is discovered, a quantity of powdered chalk diffused in warm water should be taken, and vomiting excited as speedily as possible.

iii. Citric Acid.

1756. Citric acid is obtained by the following process from lemon or lime juice:

Boil the expressed juice for a few minutes, and when cold, strain it through fine linen: then add powdered chalk as long as it produces effervescence, heat the mixture, and strain as before: a quantity of citrate of lime remains upon the strainer, which, having been washed with cold water, is to be put into a mixture of sulphuric acid with 20 parts of water: the proportion of acid may be about equal to that of the chalk employed. In the course of 24 hours the citrate of lime will have suffered decomposition, and sulphate of lime is formed, which is separated by filtration. The filtered liquor, by careful evaporation, as directed for tartaric acid, furnishes crystallized citric acid.

The preparation of this acid is carried on by a few manufacturers upon an extensive scale; in different states of purity it is employed by the calico-printers, and used for domestic consumption. Many circumstances which have not here been alluded to, are requisite to ensure complete success in the operation; these have been fully described by Mr. Parkes, in the third volume of his *Chemical Essays*. The proportion of citric acid afforded by a gallon of good lemon-juice, is about 8 ounces.

1757. Citric acid forms crystals of a very sour taste, soluble in their own weight of water at 60°, and containing, according to Berzelius, 100 real acid + 26.5 water, a portion of which it loses by exposure to heat. The analysis of this, as well as of the other vegetable acids given by Berzelius, differs considerably from that of Gay-Lussac and Thenard, in consequence, as it would appear, of the latter chemists having neglected the exclusion of water of crystallization. Berzelius gives its constituents as follow:

Oxygen	54.831
Hydrogen	3.800
Carbon	41.369
	100.000

1758. From the analysis of citrate of lead, the representative number of citric acid appears to be 59.4; a number which closely corresponds with Berzelius's estimate of its constitution, which is

4	Proportionals of oxygen	8	×	4	=	32
3	———— hydrogen . . .	1	×	3	=	3
4	———— carbon	6	×	4	=	24
						59

The number 59. therefore, may be adopted.

1759. *Citrate of Ammonia* crystallizes with difficulty in prisms.

1760. *Citrate of Potassa* is very soluble, deliquescent, and difficultly crystallizable. It is much used in medicine as a mild diaphoretic, and is the *Salt of Riverius* of old pharmacy.

1761. *Citrate of Soda* is difficultly crystallizable in hexaëdral tables, of a saline flavour, and soluble in somewhat less than two parts of cold water.

1762. *Citrate of Lime* has been adverted to in the preparation of citric acid. It is nearly tasteless, and scarcely soluble in water, but readily soluble in solution of citric acid: when moistened it soon grows mouldy if exposed to air. It consists of

1 proportional acid = 55.5
1 ———— lime = 26.5
82.

100 parts, therefore, of citrate of lime may be regarded as composed of

67 citric acid
33 lime
100

1763. *Citrate of Baryta* is diffiultly soluble, and forms acicular crystals, readily soluble in excess of nitric acid.

1764. *Citrate of Strontia* is crystallizable and soluble.

1765. *Citrate of Magnesia* does not crystallize.

1766. *Citrate of Manganese* is formed by digesting moist protoxide of manganese in citric acid; it produces white arborescent crystals.

1767. *Citrate of Iron.* The action of citric acid on the oxides of iron has not been examined.

1768. *Citrate of Zinc.* Zinc dissolves in citric acid with effervescence: citric acid readily dissolves the oxide of zinc, and the solution deposits small crystals, scarcely soluble in water, and of an astringent taste.

1769. *Citrate of Tin.* Neutral citrate of potassa forms no precipitate either in protomuriate or permuriate of tin.

1770. *Citrate of Copper.* Citric acid forms a pale blue precipitate in solution of sulphate and nitrate of copper.

1771. *Citrate of Lead* is thrown down in the state of a nearly insoluble powder when citric acid is added to nitrate of lead. It consists of

59.4 acid
112. oxide
171.4

1772. *Citrate of Antimony* is unknown.

1773. *Citrate of Bismuth* is an insoluble white compound.

1774. *Citrate of Cobalt* appears to be a soluble salt.

1775. *Citrate of Uranium*, formed by digesting oxide of uranium in citric acid, is a soluble and difficultly crystallizable salt.

1776. *Citrate of Nickel* is not thrown down by adding either citric acid or citrate of potassa to the solutions of nickel.

1777. *Citrate of Mercury.* Both the *protocitrate* and *percitrate* of mercury are insoluble, and thrown down when citric acid or a soluble citrate is added to the solutions of mercury.

1778. *Citrate of Silver* is an insoluble white powder, which blackens by exposure to light.

iv. Malic Acid.

1779. The existence of a peculiar acid in the juice of apples, was shown by Scheele, in 1785. He obtained it by adding solution of acetate of lead to the expressed juice of unripe apples, by which a *malate of lead* was formed, and afterwards decomposed by sulphuric acid. Vauquelin obtained it by a similar process, from the juice of the *houseleek*. The same acid exists, according to Braconnot, in the berries of the *mountain-ash*, from which it was first obtained by Mr. Donovan in 1815, and called by him *sorbic acid;* the apparent differences between the malic and sorbic acids, are referable to the impurities of the former. Mr. Donovan has given the following process for its preparation. (*Phil. Trans.*, 1815.) Express the juice of the ripe berries, and add solution of acetate of lead, filter, and wash the precipitate with cold water, then pour boiling water upon the filter, and allow it to pass through the precipitate into glass jars; after some hours crystals are deposited, which are to be boiled with 2.3 times their weight of sulphuric acid, specific gravity 1.090. The clear liquor is to be poured off, and, while still hot, a stream of sulphuretted hydrogen is to be passed through it, to precipitate the remaining lead; the liquid is then filtered, and when boiled so as to expel the sulphuretted hydrogen, is a solution of the pure vegetable acid.

How obtained

Malic acid may also be obtained by steeping sheet-lead in the juice of apples; in a few days, crystals of malate of lead form, which may be collected and decomposed by the very careful addition of dilute sulphuric acid.

Properties.

1780. Malic acid, when carefully prepared, is a colourless liquid, very sour, and not susceptible of crystallization. It forms crystallizable salts with many of the metallic oxides, which, however, have scarcely been examined with such precision as to enable us to determine the representative number of malic acid. A detailed account of what is known respecting them will be found in M. Braconnot's Memoir, (*Annales de Chim et Phys.*, Tom. vi.) His analysis of the crystallized *malate of lead* gives its composition thus:

Acid	100.
Oxide of lead . .	157.4

If we deduce the number for the acid, from this datum, it will be 71.1, a number which closely corresponds with the other analyses of the same author.

1781. The ultimate component parts of this acid, according to Vauquelin, are

Hydrogen	16.8
Carbon	28.3
Oxygen	54.9
	100.0

v. Gallic Acid.

How obtained

1782. This acid derives its name from the *gall-nut*, whence it was first procured by Scheele. It may be obtained by the following process:

Digest bruised galls in boiling water, with about one-sixth their weight of vellum cuttings, for some hours; then allow the mixture to cool, and filter it. Add to the filtered liquor a solution of acetate of lead, as long as it occasions any precipitate; pour the whole upon a filter, wash the precipitate with warm water, and digest it in very dilute sulphuric acid; filter, and having saturated the clear liquor with chalk, evaporate to dryness. Introduce the dry mass into a retort placed in a sand-bath, and upon the application of heat a portion of water will first rise, and afterwards a crystalline sublimate of gallic acid.

1783. There are many other processes for obtaining this acid, among which the following deserve notice: Moisten bruised gall-nuts, and expose them for four or five weeks, to a temperature of about 80°. A mouldy paste is formed, which is to be squeezed dry, and digested in boiling water; it then affords a solution of gallic acid, which may be whitened by animal charcoal, and which, on evaporation, yields gallic acid, crystallised in white needles.—BRACONNOT, *Annales de Chim. et Phys.*, Tom. ix. 181.

Boil an ounce of powdered galls in 16 ounces of water down to 8, and strain; dissolve 2 ounces of alum in water, precipitate the alumina by carbonate of potassa, and, after edulcorating it, stir it into the decoction; the next day filter the mixture; wash the precipitate with warm water, till this will no longer blacken sulphate of iron; mix the washing with the filtered liquor, evaporate, and the gallic acid will be obtained in acicular crystals.—FEDLER, URE's *Dictionary*.

Properties. 1784. Gallic acid, when pure, is in whitish crystals, of a sour taste, and which exhale a peculiar smell when heated. *It dissolves in about* 10 parts of water at 60°, and in two parts at 212°. *It is also soluble* in alcohol and in ether. When repeatedly sublimed, this acid is altered and in part decomposed. It consists, according to Berzelius (*Annals of Philosophy*, Vol. v.) of

Hydrogen	5.00
Carbon	56.64
Oxygen	38.36
	100.00

And, according to the same authority, *gallate of lead* is composed of

Gallic acid	100
Oxide of lead	174

These proportions give the number 64.3 as the representative of gallic acid.

1785. The combinations of pure gallic acid with metallic bases have scarcely been examined, and consequently we have no accurate chemical history of the *gallates*. Their solutions are all very prone to decomposition, and acquire a deep brown colour. This acid forms no precipitate in solutions of potassa or of soda, but when dropped into lime-water, baryta water, or strontia water, it occasions the separation of a difficultly soluble gallate of those earths. It also causes a precipitate in solutions of zirconia, glucina, and yttria.

1786. When an infusion of galls is added to certain metallic solutions, it forms precipitates composed of tannin, gallic acid, and the metallic oxide, and as these are often of different colours, the infusion is employed as a test for such metals. The following metals in solution are thus thrown down, of the annexed colours.

METAL.	SOLUTION.	PRECIPITATE.
MANGANESE	Neutral protomuriate	Dirty yellow
IRON	Neutral protosulphate	Purple
Ditto	Permuriate	Black
ZINC	Muriate	Dirty yellow
TIN	Acid protomuriate	Straw-colour
Ditto	Acid permuriate	Fawn-colour
CADMIUM . .	Muriate	?
COPPER . . .	Protomuriate	Yellow brown
Ditto	Pernitrate	Grass green
LEAD	Nitrate	Dingy yellow
ANTIMONY . .	Tartrate of antimony and potassa	Straw colour
BISMUTH . . .	Tartrate of bismuth and potassa	Yellow and copious
COBALT . . .	Muriate	0
URANIUM . .	Sulphate	Bluish black
TITANIUM . .	Acid muriate	Brown
Ditto	Neutral sulphate	Blood red
CERIUM . . .		Yellowish
TELLURIUM .		Yellow
ARSENIC . . .	White oxide	Little change
Ditto	Arsenic acid	0
MOLYBDENUM		Brown
NICKEL . . .	Sulphate	Green
MERCURY . .	Acid protonitrate	Yellow
Ditto	Acid pernitrate	Yellow
Ditto	Corrosive sublimate	0
OSMIUM . . .	Aqueous solution of oxide	Purple becoming blue
RHODIUM . .		
PALLADIUM .		
SILVER	Nitrate	Curdy and brown after some time
GOLD	Muriate	Deep brown
PLATINUM . .	Muriate	Brownish green

The omitted metals are either not precipitated, or their action has not been examined.

1787. Of these compounds, the *tannogallate of iron* is of the most importance, as forming the basis of writing ink, and of black dyes.

When an infusion of galls is dropped into a solution of sulphate of iron, it produces a deep purple precipitate, which is a very long time in subsiding; it becomes black by exposure to air. In writing ink, this precipitate is retained in suspension by mucilage, and the following proportions appear the best which can be used.

Finely bruised galls, 3 ounces
Green vitriol (protosulphate of iron)
Logwood shavings
Gum arabic, of each 1 ounce
Vinegar, 1 quart.

Put these ingredients into a bottle, and agitate them occasionally during twelve or fourteen days; then allow the coarser parts to settle, and pour off the ink for use.

The tendency of ink to become mouldy is much diminished by keeping a few cloves in the ink-bottle, or by dissolving in each pint of the ink about three grains of corrosive sublimate.

The colour of common writing-ink is apt to fade, in consequence of the decomposition of its vegetable matter; and when thus illegible, it may often be restored by washing the writing with vinegar, and subsequently with infusion of galls. Acids also destroy its colouring matter, and those inks which resist their action, contain some other colouring principle, usually finely powdered charcoal. Common writing ink is, for this reason, much improved by dissolving in the quantity abovementioned about an ounce of *Indian ink* which is lamp-black made into a cake with isinglass.

In dyeing black, the stuff is first impregnated with a solution of the gall-nut, and afterwards the colour is brought out by the application of sulphate, or acetate of iron (1611.)

Upon these subjects much valuable information will be found in LEWIS's *Philosophical Commerce of the Arts*, and in AIKIN's *Dictionary*.

1788. In the *Philos. Trans.* for 1817, I have described the properties of a species of galls from China, which furnish very pure gallic acid, and which, could they be abundantly obtained, would certainly prove a valuable substitute for common galls, in many of the processes in which they are employed.

VI. BENZOIC ACID.

1789. Benzoic acid may be obtained by sublimation from *benzoin*. which is a resinous exudation from the *Styrax benzoe* of Sumatra; it also exists in the *Balsam of Peru* and of *Tolu*. If these substances be How obtained heated in a crucible, with a cone of paper attached to its mouth, the acid condenses in it in fine acicular crystals, which were formerly called *flowers of benzoin*. A good process for procuring this acid is that recommended by Mr. Hatchett, which consists in digesting benzoin in sulphuric acid, when it affords a copious sublimate of pure benzoic acid. (*Additional Experiments on Tannin, Phil. Trans.*, 1808.) It may also be obtained by boiling a pound and a half of powdered benzoin with 4 ounces of quicklime, in 6 or 8 quarts of water. When cold the clear liquor is decanted, and the residuum again boiled in half the former quantity of water. The liquors thus obtained are boiled down to half their bulk, filtered, and mixed with muriatic acid, as long as it occasions a precipitate, from which the liquor is poured off, and when dry it is put into an earthen vessel, placed in a sand heat, and sublimed into paper cones.

In the tenth volume of Nicholsons's *Journal* I have detailed several experiments on benzoin, and have shown the relative quantity of acid afforded by the several processes which have been recommended for obtaining it.

Characters. 1790. Benzoic acid, when it has been thus sublimed, is in the form of soft feathery crystals, of an acrid and slightly sour taste, soluble in about 30 parts of boiling water, and very sparingly soluble in cold water. It is much more soluble in alcohol, and this solution easily furnishes it in prismatic crystals.

1791. Berzelius' analysis gives the following as the components of this acid, and of the benzoate of lead:

Hydrogen	5.16	
Carbon	74.41	
Oxygen	20.43	
	100.00	
Benzoic acid	100	=194
Oxide of lead	94	

Whence it appears that the representative number of benzoic acid is 119.

1792. *Benzoate of Ammonia* forms deliquescent plumose crystals, very soluble in water. Berzelius recommends this salt as a precipitant of iron, which it throws down of an orange colour.

1793. *Benzoate of Potassa* is a very soluble deliquescent salt; if it be digested with benzoic acid, a *bibenzoate of potassa* results, which, according to Bucholz (*Annales de Chimie*, lxxxiv.) forms acicular and lamellar crystals, requiring ten parts of water for their solution.

1794. *Benzoate of Soda* forms efflorescent crystals, very soluble in water.

1795. *Benzoate of Lime* forms acicular crystals, sparingly soluble in cold water. Vauquelin found this salt in the urine of the cow Benzoate of ammonia forms a copious white precipitate when added to muriate of lime, which is soluble in hot water.

1796. *Benzoate of Baryta* is soluble and crystallizable.

1797. *Benzoate of Strontia* is also a soluble salt.

1798. *Benzoate of Magnesia* forms soluble plumose crystals.

1799. *Benzoate of Manganese* forms beautiful prismatic crystals.

1800. *Benzoate of Iron.* Benzoate of ammonia forms an insoluble *perbenzoate* when added to solutions of peroxide of iron, of a yellow colour: in the protosalts of iron it also forms a white precipitate.

1801. *Benzoate of Zinc* forms soluble acicular crystals when there is excess of acid: the neutral benzoate is insoluble.

1802. *Benzoate of Tin* is insoluble.

1803. *Benzoate of Copper* is a fine blue insoluble compound.

1804. *Benzoate of Lead* is insoluble except there be excess of acid; it then forms nacreous crystals.

1805. *Benzoate of Bismuth* forms white acicular crystals, permanent in the air, soluble in water, and sparingly soluble in alcohol. (TROMMSDORF, *Ann. de Chim.*, xi.) When benzoate of ammonia is added to acid nitrate of bismuth, it forms an insoluble white precipitate; Trommsdorf's salt therefore is probably a *bibenzoate*.

1806. *Benzoate of Cobalt.* Benzoate of ammonia forms no precipitate in solutions of cobalt.

1807. *Benzoate of Uranium* is a difficultly soluble straw-coloured compound, when formed by adding benzoate of ammonia to nitrate of uranium.

1808. *Benzoate of Nickel.* Solutions of nickel are only rendered slightly turbid by benzoate of ammonia, benzoate of nickel is probably therefore a soluble salt.

1809. *Benzoate of Mercury.* Benzoic acid forms white precipitates in the solutions of mercury.

1810. *Benzoate of Silver*, obtained by digesting moist oxide of silver in benzoic acid forms acicular crystals; but benzoate of ammonia forms an abundant insoluble precipitate in solution of nitrate of silver.

1811. *Benzoate of Alumina* forms arborescent crystals.

Besides the vegetable acids which have now been described, there are a few others of considerably inferior interest and importance; namely, the

1812. *Moroxylic acid*, discovered by Klaproth, in the bark of the *morus alba*, or *white mulberry* (NICHOLSON'S *Journal*, vii.) An exudation was observed upon this bark, which proved to be a compound of a peculiar acid and lime, or a *moroxylate of lime;* its solution was decomposed by acetate of lead, and the *moroxylate of lead thus obtained* decomposed by dilute sulphuric acid, furnished a solution of moroxylic acid, which gave acicular crystals on evaporation. This acid has the taste of succinic acid; it is soluble in water and alcohol, and does not, like some of its salts, form precipitates in metallic solutions. The quantity of this acid examined by Klaproth, was so small as to leave some doubt respecting its distinct nature.

1813. *Boletic acid* was obtained by Braconnot from the *boletus pseudo-ignarius* (*Ann. de Chim.* Tom. lxxx.) by cautiously evaporating its expressed juice to the thickness of syrup, digesting it in alcohol, dissolving the residue in water, and adding nitrate of lead to the aqueous solution; the precipitate washed and diffused through water, was decomposed by sulphuretted hydrogen; the liquor was then filtered and evaporated till it formed crystals, which were purified by solution in alcohol and evaporation. These crystals are boletic acid; they are prismatic, and require 180 parts of water at 68°, and 45 of alcohol for their solution, which reddens blues and precipitates nitrate of lead, and the salts containing the peroxide, but not those of the protoxide of iron. This acid sublimes with little alteration, when heated. Braconnot has examined the *boletates of ammonia, potassa, lime*, and *baryta*, but his researches have not as yet been confirmed by any other chemist.—THOMSON'S *Syst. 6th edit.* ii. 157.

1814. *Fungic acid* was procured by the same chemist from the *boletus juglandis*, and some other fungi; it is deliquescent and uncrystallizable.—*Annales de Chimie*, lxxxvii.

1815. *Kinic acid* was discovered by Vauquelin, in *Cinchona*. When a strong cold infusion of this bark is set aside, crystals of *kinate of lime* are sparingly deposited by it, which may be decomposed by oxalic acid. The kinic acid is crystallizable, sour, and bitter: the *kinates* are for the most part soluble salts; it is chiefly distinguished by forming no precipitate in solutions of lead and silver.—*Annales de Chimie*, lix.

1816. In the astringent root of the *Krameria triandra*, M. Peschier has announced the existence of what he considers as a distinct substance, which he calls *krameric acid*.—*Journal de Pharmacie*, vi.

1817. M. Braconnot has given the term *Ellagic acid* (from the word *galle* reversed) to an acid body which he has detected, along with gallic acid, in infusion of galls, but its characters have been but imperfectly ascertained.

1818. *Zumic acid* was discovered by the same chemist in vegetable substances, which have undergone acetous fermentation—THOMSON's *Syst.* Vol. ii. p. 189.

SECTION XVIII. *Of the Parts of Plants.*

1819. IN the preceding Sections the principal proximate components of vegetables have been described, and the composition of some of their detached parts has been adverted to; such of these as have not been previously noticed and as have been examined with any degree of precision, remain to be described in this Section under the heads of

Roots.
Barks.
Woods.
Leaves.
Flowers.
Seeds.
Fruits.
Bulbs.
Lichens.
Fungi.

i. ROOTS.

1820. *a. Ipecacuanha.* This root is the produce of the *Callicocca Ipecacuanha* (LINNÆAN *Trans.* vi.) It has been examined by MM. Pelletier and Majendie, and an account of their researches is published by M. Robiquet, in the *Annales de Chimie et Phys.* iv. 172. 100 parts of this root, deprived of the woody fibre which traverses its centre afforded

Fatty matter	2
Emetine	14
Gum	16
Starch	18
Woody fibre	48
A trace of wax	
Loss	2
	100

The means of separating the emetic principle have already been described (1595).

1821. *b. Valerian*, the root of the *Valeriana officinalis*, has been examined by Trommsdorf (*Annales de Chimie*, lxx.) The recent root loses about three-fourths its weight in drying. It affords, when distilled with water, an aromatic volatile oil; it also contains starch, gum, resin, and extractive.

1822. *c. Turmeric* is the root of the *Curcuma longa*, a plant cultivated in the East Indies, and used as a condiment, especially in *Curry powder*. Digested in water or alcohol, it furnishes a large proportion of yellow colouring matter, which would be very useful to the dyer, could it be rendered permanent. Most of the acids render it paler, and the alcalis change it to a deep brick-red; hence its use as a test of the presence of alcaline matter. It is also reddened by boracic acid, and by muriatic acid gas.

1823. *d. Madder* is the root of the *Rubia Tinctorum*, and is an article of great importance in dyeing; it grows wild in most parts of the south of Europe, and is largely cultivated in some parts of Holland and the Levant; its red colour is apt to be injured by drying, a process requiring much caution. Good madder has a strong and peculiar smell; it exhibits, when cut, a cortical and a woody part of a red colour, intermixed in the former with yellow spots. The red portion is most soluble.—AIKIN's *Dictionary*. Art. DYEING. BERTHOLLET, *Elem. de Teinture*, ii.

1824. *e. Rhubarb* is the root of the *Rheum palmatum*, largely cultivated in the northern parts of China; its colour is brown, with streaks of red and white. The following are the component parts, separable from the finest kinds of Turkey rhubarb.—BRANDE, *Quarterly Journal of Science and the Arts*, x. 291.

Water	8.2
Gum	31.0
Resin	10.0
Extract, tan, and gallic acid	26.0
Phosphate of lime	2.0
Malate of lime	6.5
Woody fibre	16.3
	100.0

1825. *Liquorice*, the root of the *Glycyrrhiza glabra*, has been examined by M. Robiquet, who found in it the following substances.—*Annales de Chimie*, lxx.

i. Starch.
ii. Gluten.
iii. Liquorice sugar.
iv. Phosphate and malate of lime and magnesia.
v. An acrid oil.
vi. A crystallizable substance resembling asparagin.
vii. Woody fibre.

The sugar is soluble in water and in alcohol, but not convertible into alcohol by fermentation; nor into oxalic acid by the action of nitric acid.

1826. *Jalap*, the root of the *Convolvulus Jaloppa*, is employed in medicine as a cathartic. It is imported from South America. It has not been submitted to any accurate chemical analysis, but its activity is generally regarded as chiefly resident in its resin. The finest and densest jalap affords about 12 *per cent.* of resin, when digested in alcohol; water takes up about 30 or 35 *per cent.* of the remainder, and the residue appears to be inert woody fibre.

1827. *Gentian* is the root of the *Gentiana lutea*; according to Mr. Henry (*Annals of Philosophy*, xvi. 89,) it contains the following substances:

i. A substance resembling bird-lime.
ii. A resin combined with an oil, which gives to gentian its peculiar odour.
iii. A bitter extractive principle.
iv. Gum and colouring matter.
v. Phosphate of lime?

ii. Barks.

1828. *a. Cinchona.* The varieties of Peruvian bark have been examined by MM. Pelletier and Caventou. In the *cinchona lancifolia*, or *pale bark*, they found the following constituent parts: Cinchona lancifolia, pale.

i. Cinchonine, combined with kinic acid.
ii. Green fatty matter.
iii. Red and yellow colouring matter.
iv. Tannin.
v. Kinate of lime.
vi. Gum.
vii. Starch.
viii. Lignin.

1829. *Cinchonine*, according to the above chemists, is a salifiable base, forming white acicular crystals, and requiring 7000 parts of water for solution; dissolved in alcohol it has a bitter taste. It is difficultly soluble in the fixed and volatile oils and in ether.

1830. *Sulphate of Cinchonine* is easily crystallizable, and moderately soluble; it consists of

Cinchonine	100
Sulphuric acid.	13

1831. *Muriate of Cinchonine* is much more soluble than the sulphate, and contains

Cinchonine	100
Muriatic acid	7.9

1832. *Nitrate of Cinchonine* appears to be uncrystallizable. Gallic, oxalic, and tartaric acids form difficultly soluble salts with cinchonine; the precipitate occasioned by dropping tincture of galls into infusion of pale bark is a *gallate of Cinchonine*.

1833. In the *yellow bark* (*cinchona cordifolia*) MM. Pelletier and Cordifolia, yellow.

Caventou discovered a salifiable base, which they term *Quinine*, the sulphate of which is composed of

Quinine	100
Sulphuric acid	10.9

1834. *Acetate of Quinine* forms bundles of flat acicular crystals, while the corresponding salt of cinchonine crystallizes in small tables. The *gallate*, *oxalate*, and *tartrate of quinine*, are nearly insoluble, but quinine is very soluble in sulphuric ether.

Oblongifolia, red. 1835. In the *red bark* (*cinchona oblongifolia*) the two salifiable bases above described are found united.—*Quarterly Journal of Science and the Arts*, x. 388.

1836. *b*. *Cascarilla*, the bark of the *Croton Eleutheria* contains, according to Trommsdorff—*Annales de Chimie*, xxii.

	Parts.
Mucilage and bitter principle	864
Resin	688
Volatile oil	72
Water	48
Woody fibre	3024
	4696

1837. *c*. The bark of the *horse chestnut* (*Æsculus hippocastanum*,) has been partially examined by M. Henry (*Annales de Chimie*, lxxvii) It appears to contain scarcely any resin; water and diluted alcohol dissolve nearly the whole of its soluble contents, which are chiefly extractive and mucilage. Tincture of galls does not render its infusion turbid, it does not therefore probably contain the peculiar substances discovered in Peruvian bark.

iii. WOODS.

1838. *a*. *Brazil Wood* is the produce of the *Cæsalpina crista*, growing in Brazil, in the Isle of France, Japan, and other countries: the wood is hard and heavy, and though pale when recent, it acquires a deep red colour by exposure. Digested in water it affords a fine red infusion, of a sweetish flavour; the residue, which appears nearly black, imparts much of its colour to alcaline liquors. With alcohol it gives a deep red tincture: alcalis and soap convert its red colour to a fine purple, hence paper tinged with Brazil wood is sometimes used as a test for alcalis; acids render it yellow; alum produces a fine crimson lake with infusion of Brazil wood; muriate of tin forms with it a crimson precipitate, bordering on purple; the salts of iron give a dingy purple colour. Sulphuretted hydrogen destroys the colour of infusion of brazil wood, but it re-appears on expelling the gas.—CHEVREUL. *Annales de Chimie*, lxvi.

1839. *b*. *Red Sandal*, or *Saunders*, is the wood of the *Pterocarpus santalinus*, a native of several parts of India. Its deep red colouring matter is insoluble in water, but readily soluble in alcohol; it is chiefly employed for colouring a few pharmaceutical tinctures. The insolubility of its colouring principle in water furnishes a ready mode of distinguishing between it and brazil wood; and its solubility in alcohol renders it probable that it is of a resinous nature.

1840. *c. Logwood*, the produce of the *Hæmatoxylon campechianum*, has already been noticed as containing a peculiar colouring principle (1586). It imparts a fine purple or crimson colour to pure water, but its tint is altered by the slightest metallic impregnation; alcalis deepen it, and acids render it paler; alum forms with it a violet-coloured lake; sulphate of iron renders the infusion of logwood deep purple, or nearly black; sulphate of copper and acetate of lead throw down brown and purple precipitates; and muriate of tin precipitates the whole of the colouring matter, in the form of a purple compound. The colours which logwood produces are for the most part very perishable.—BANCROFT, *on Permanent Colours*, ii. 338. CHEVREUL, *Annales de Chimie*, lxvi. 254.

iv. LEAVES.

1841. *a. Senna.* According to Lagrange (*Annales de Chimie*, xxvi.) the leaves of the *Cassia senna* are characterized by containing a peculiar extractive principle, which, by long boiling, passes into a resinous substance, in consequence of absorbing oxygen; they also contain a resin which resists the action of water, and is soluble in alcohol; the whole of the soluble matter amounts to about one-third the weight of the senna. In the *London Medical Repository*, Vol. xv., 169, the effects of the various re-agents on infusion of senna are detailed by Mr. Batley.

1842. *b. Nightshade.* The leaves of the *Atropa Belladonna* contain, according to Vauquelin (*Annales de Chimie*, lxxii),

i. Vegetable albumen.
ii. A bitter narcotic principle.
iii. Nitrate, muriate, sulphate, binoxalate, and acetate of potassa.

Dr. Brandes has announced the existence of a new vegetable alcali in this plant, which he calls *atropia*. It forms brilliant acicular crystals, tasteless, and difficulty soluble in water and alcohol. It affords distinct salts with the acids; the *Sulphate of Atropia* consists of

Sulphuric acid	36.52
Atropia	38.93
Water	24.55
	100.00

1843. *c. Hyoscyamus Niger*, or *Henbane*. In the leaves of this plant Dr. Brandes has also ascertained the presence of a peculiar, and highly poisonous salifiable base which he calls *hyoscyama*. With the acids it forms characteristic salts; it crystallizes in long prisms.

v. FLOWERS.

1844. The colouring matter of most flowers is extremely fugitive, and is generally much changed by mere exsiccation. They usually communicate their colour to water; the infusion of blue flowers is generally reddened by acids, and changed to green or yellow by alcalis; that of yellow flowers is made paler by acids, and alcalis render it brown; the red infusion of many flowers is exalted in tint by acids, and changed to purple, and in some instances, to green by alcalis.

It is probable that one and the same principle gives colour to several of the blue and red flowers, but that the presence of acid in the latter produces the red; the petals of the red rose, triturated with a little carbonate of lime and water, give a blue liquor; alcalis render it green, and acids restore the red.

1845. A colouring matter, analogous to that of the violet, exists in the petals of red clover, in the red tips of those of the common daisy, of the blue hyacinth, the holly-hock, lavender, in the inner leaves of of the artichoke, and in numerous other flowers; reddened by an acid, it colours the skin of several plums, and the petals of the scarlet geranium and pomegranate. Some flowers which are red, become blue by merely bruising them; this is also the case with the colouring matter of red cabbage leaves, and of the rind of the long radish. Mr. Smithson has suggested that the reddening acid is in these cases the carbonic, which escapes on the rupture of the vessels which enclose it.

1846. The petals of the common *corn-poppy*, rubbed upon paper, give a purple stain, little altered by ammonia or carbonate of soda, but made green by caustic potassa. The infusion of poppy-petals in very dilute muriatic acid, is florid red; chalk added, renders it of the colour of port wine; carbonate of soda in excess gives the same colour, but excess of potassa changes it to green and yellow. The expressed juice of the black mulberry possesses nearly the same properties.—SMITHSON, *Phil. Trans.* 1818, 110.

1847. The flowers of the *carthamus tinctorius*, or *safflower*, cultivated chiefly in Spain and the Levant, contain a yellow colouring matter, easily soluble in water, and a red, soluble in *alcohol and weak alcaline* liquors; the latter only is employed. *Rouge is the red* colouring matter of the carthamus, obtained by digesting *the washed* flowers in solution of carbonate of soda, and adding lemon juice, *which throws* it down in the form of a fine powder, which is dried and mixed with a portion of powdered talc; carthamus is also used for dyeing silk. The details of the analysis of carthamus will be found in the Essays of Dufour and Marchais.—*Annales de Chimie*, xlviii.

vi. SEEDS.

1848. Starch is an essential component of the greater number of seeds, and it is generally united in them with a variable portion of gluten, and often of fixed and of volatile oil. The component parts of wheat-flour, and of several esculent grains, have already been stated (1581,) and a variety of curious details respecting them will be found in EINHOFF's *Papers*, in GEHLEN's *Journal*.

Sir H. Davy has also examined a number of seeds, with a view to determine their relative nutritive powers; the results of his experiments are seen in the table at the end of this section.

1849. *Almonds*, the seed of the *amygdalus communis*, consist of an albuminous substance and oil; the latter may be obtained by expression, five pounds yielding about one pound of cold drawn oil, and about a pound and a half when aided by heat. The bitter almond affords by pressure an oil analogous to that from the former; but if the expressed cake be distilled with water, a portion of volatile oil, eminently poisonous, and smelling strongly of the almond, is obtained; this oil is used as a flavouring material by confectioners, and by the manufacturers of noyau. In the *Philosophical Transactions* for 1811, Mr. Brodie has detailed a variety of experiments illustrative of its action as a poison, in which, as well as from its odour, it appears identical nearly with hydrocyanic acid.

1850. *Lentiles*, the seed of the *ervum lens*, contain, according to Einhoff, in 3840 parts,

Woody fibre	720
Albumen	44
Earthy phosphates	22
Extractive, soluble in alcohol	120
Gum	230
Starch	1260
Gluten	1433
Loss	11
	3840

1851. The seeds of the *white lupine* (*lupinus albus*) contain, according to Fourcroy and Vauquelin (*Ann. du Muséum*, No. xxxvi.), gluten, and a green acrid oil, with a considerable portion of phospate of lime and magnesia, but no starch or sugar.

1852. *Coffee*, the seed of the *Coffea Arabica*, has been examined both in its raw and roasted state. From 64 parts of raw coffee, Cadet (*Ann. de Chimie*, lviii.) obtained

Gum	8.
Resin and bitter extract	2.0
Gallic acid	3.5
Insoluble matter	43.5
Loss, including a trace of albumen	7.0
	64.

Hermann has given the following comparative analysis of coffee from the Levant and from Martinique (Crell's *Annals*, ii.), the results of which differ much from those of Cadet:

	Levant.	Martinique:
Resin	74	68
Extractive	320	310
Gum	130	144
Fibrous matter	1335	1386
Loss	61	12
	1920	1920

When coffee is roasted it undergoes a peculiar change of composition, attended by the formation of tan, and a volatile, fragrant, and aromatic principle; but in this state it has not been examined with any precision.

1853. *Pepper*. The seed of the *piper nigrum* has not been satisfactorily analyzed: it imparts its acrimony to alcohol and to water; it contains a species of volatile oil, with starch and extractive matter.—Nicholson's *Journal*, ii.

1854. *Mustard.* The seed of the *sinapis nigra* derives its acrimony from a volatile oil; it also contains a tasteless fixed oil, albumen, gum, and traces of sulphur and earthy salts.

1855. The seeds of the *lycopodium clavatum*, or *common club moss*. have been analyzed by Bucholz. (GEHLEN's *Journal*, vi.) From 1000 parts he obtained

Fixed oil	60
Sugar	30
Mucilage	15
Insoluble residue	895
	1000

This seed has the appearance of a fine yellow powder, which deflagrates when projected into the flame of a candle; it is used in theatres to imitate lightning; and the German apothecaries employ it to prevent the adhesion of pills.

1856. *Annotta* is the produce of the *bixa orellana*, a tree cultivated in various parts of America. When the capsules are ripe, the seeds are bruised and steeped for several weeks in water, until converted into a pulp, which is allowed to putrefy, and being diffused through a fresh portion of water, is heated till a scum rises, which is successively removed as it forms, and being carefully dried, is made up into cakes, and wrapped in palm leaves for exportation.

Annotta is soluble in water and alcohol; the solutions have a disagreeable smell, and are of an orange colour; alcalis render it more soluble and increase its colour: alum and the acids separate it from its solutions in the form of a yellow sediment: it is used for dyeing silk and colouring cheese.

vii. FRUITS.

Their contents.

1857. The acid matter contained in fruits is either the tartaric oxalic, citric, or malic; or a mixture of two or more of them; but the nature and proportion of the acid varies at different periods of their growth; gluten and starch are found in some fruits, and a gelatinizing substance, which has sometimes been regarded as identical with animal jelly, but which is probably a compound of gum and one or more vegetable acids.

1858. Most of our common fruits also contain sugar, and it exists in all those the juice of which is susceptible of vinous fermentation. In some fruits the quantity of sugar is increased by mashing and exposure to air; this is remarkably the case with some of the rough-flavoured apples used for cider, the pulp of which becomes brown, and at the same time sweet by a few hours' exposure.

1859. The colouring matter of fruits seems in most cases to bear a strong resemblance to that of flowers. The red juice of the mulberry was found to exhibit the same characters as the colouring principle of the wild poppy; carbonated alcalis render it blue, but caustic potassa changes it to green and yellow: the juice of red currants, cherries, elder berries, and privet berries, and the skin of the buckthorn berry, appear to contain a similar colouring principle.

1860. The unripe berries of the buckthorn furnish a juice, which, when inspissated, is known under the name of *sap green*. It is soluble in water, and rendered yellow by carbonate of soda and caustic potassa; the acids redden it, and carbonate of lime restores it to green, which is therefore probably the proper colour of the substance. (SMITHSON, *Phil. Trans.*, 1818, p. 116).

1861. The fruit of the *wild cucumber* (*cucumis elaterium*) furnishes a very acrid juice, which deposits the powerful cathartic known under the name of *elaterium*. This substance occurs in commerce in thin cakes of a greenish colour and bitter taste; it derives its cathartic power from a small portion of a very active principle, which Dr. Paris has called *Elatin*: (*Pharmacologia*, 223, 3d. Edit.) from 10 grains of elaterium he obtained

Water	0.4
Extractive	2.6
Fecula	2.8
Gluten	0.5
Woody matter	2.5
Elatin Bitter principle	1.2
	10.

viii. BULBS.

1862. The *potatoe*, which is the bulbous root of the *solanum tuberosum*, has been examined by Dr. Pearson and by M. Einhoff; from 100 parts, the latter chemist obtained

Starchy matter	22
Albumen and mucilage	5.4
	27.4

The average quantity of nutritive matter contained in the potatoe, amounts to about one-fourth its weight. When potatoes become sweet by exposure to frost, a portion of the mucilage passes into the state of sugar, for Einhoff found the quantity of starch undiminished.

1863. *Garlic*, or the bulbous root of the *allium sativum*, has been examined by Cadet. (*Ann. de Chim.*, lix.) It loses by drying about two-thirds of its weight; its juice is viscid, and very slightly sour; it yields coagulated albumen when heated, and when distilled with water furnishes an acrid oil having a strong odour of garlic.

1864. The bulb of the *Allium Cepa*, or *Onion*, has been analyzed by Fourcroy and Vauquelin (*Ann. de Chimie*, lxv.). The juice of this root, when exposed to a temperature of about 70°, forms a quantity of vinegar, and deposits a sediment having the characters of gluten combined with oil and sulphur. In the acetous solution is contained a substance having the properties of manna, and which is probably a product of the fermentation, for none could be detected in the recent juice.

1865. *Squill*, the bulbous root of the *Scilla maritima* contains, according to Vogel, (*Annales de Chim.* lxxxiv.) a peculiar bitter principle, which he terms *Scillitin*, combined with gum, and a considerable portion of tannin.

ix. LICHENS.

1866. There are several lichens which abound in colouring matter; of these the most remarkable is the *Lichen rocella*, which grows in the South of France and in the Canary Islands, and which affords the beautiful but perishable blue called *litmus*, *archil*, or *turnsole*. The moss is dried, powdered, mixed with pearlash and urine, and allowed to ferment, during which it becomes red, and then blue; in this state it is mixed with carbonate of potassa and chalk, and dried. It is used for dyeing silk and ribands, and by the chemist is a most delicate test of acids, which it indicates by passing from blue to red; the blue colour is restored by alcalis, which do not render it green. *Cudbear* appears to be a similar preparation of the *lichen tartareus*.—BANCROFT *on Colours*, i., 300.

Mr. Smithson has thrown some doubt upon the use of alcalis in the precipitation of litmus, for he found its tincture produce no change on solutions of muriate of lime, nitrate of lead, muriate of platinum and oxalate of potassa; he at the same time suggests the idea of its being a compound of a vegetable principle with potassa.—*Phil. Trans.*, 1818, p. 112.

1867. The *Lichen Islandicus*, or *Iceland Moss*, has been subjected to analysis by Berzelius. (*Annales de Chimie*, xc.) He obtained from it the following substances:

Syrup	3.6
Bi-tartrate of potassa	1.9
Tartrate of lime	
Phosphate of lime	
Bitter principle	3.0
Wax	1.6
Gum	3.7
Colouring extract	7.0
Starch	44.6
Insoluble starchy matter	36.6
	102.0

x. FUNGI OR MUSHROOMS.

1868. M. Braconnot, who has lately examined many fungi with minute attention, has given the name *fungin* to the insoluble spongy portion which they contain, and which in many respects resembles lignin: he has also detected in them two peculiar acids, which he terms *fungic acid* (1814) and *boletic acid* (1813); the method of extracting which has been above described. A peculiar fatty matter, or adipocer, has been found by Vauquelin and Braconnot, in several of the fungi; an albuminous substance, and salts, some of which are boletates and fungates, have also been detected in them, but the analyses are too abstruse, and the results too complicated, to be regarded as perfectly satisfactory. —*Annales de Chimie*, lxxix., lxxxv., *&c.*

1869. The following table, drawn up by Sir H. Davy, exhibits the relative proportions of soluble and of nutritive matter contained in 1000 parts of the different vegetable substances enumerated in the first column (*Agricultural Chemistry*, 4to., p. 131.):

VEGETABLES or VEGETABLE SUBSTANCE.	Whole quantity of Soluble or Nutritive Matter.	Mucilage or Starch.	Saccharine Matter or Sugar.	Gluten or Albumen.	Extract, or matter rendered insoluble during evaporation.
Middlesex Wheat, average crop	955	765	—	190	—
Spring Wheat	940	700	—	240	—
Mildewed Wheat of 1806	210	178	—	32	—
Blighted Wheat of 1804	650	520	—	130	—
Thick-skinned Sicilian Wheat of 1810	955	725	—	230	—
Thin-skinned Sicilian Wheat of 1810	961	722	—	239	—
Wheat from Poland	950	750	—	200	—
North American Wheat	955	730	—	225	—
Norfolk Barley	920	790	70	60	—
Oats from Scotland	743	641	15	87	—
Rye from Yorkshire	792	645	38	109	—
Common Bean	570	426	—	103	41
Dry Peas	574	501	22	35	16
Potatoes	from 260 to 200	from 200 to 155	from 20 to 15	from 40 to 30	—
Linseed Cake	151	123	11	17	—
Red Beet	148	14	121	14	—
White Beet	136	13	119	4	—
Parsnip	99	9	90	—	—
Carrots	98	3	95	—	—
Common Turnips	42	7	34	1	—
Swedish Turnips	64	9	51	2	2
Cabbage	73	41	24	8	—
Broad-leaved Clover	39	31	3	2	3
Long-rooted Clover	39	30	4	3	2
White Clover	32	29	1	3	5
Sainfoin	39	28	2	3	6
Lucerne	23	18	1	—	4
Meadow Fox-tail Grass	33	24	3	—	6
Perennial Rye Grass	39	26	4	—	5
Fertile Meadow Grass	78	65	6	—	7
Roughish Meadow Grass	39	29	5	—	6
Crested Dog's-tail Grass	35	28	3	—	4
Spiked Fescue Grass	19	15	2	—	2
Sweet-scented Soft Grass	82	72	4	—	6
Sweet-scented Vernal Grass	50	43	4	—	3
Fiorin	54	46	5	1	2
Fiorin cut in Winter	76	64	8	1	3

◆

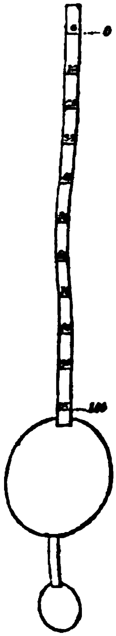
SECTION XIX. *Phenomena and Products of Fermentation.*

1870. THE term *fermentation* is employed to signify the spontaneous changes, which certain vegetable solutions undergo, placed under certain circumstances, and which terminate either in the production of an intoxicating liquor, or of vinegar; the former termination constituting *vinous*, the latter *acetous* fermentation.

The principal substance concerned in vinous fermentation is sugar; and no vegetable juice can be made to undergo the process, which does not contain it in a very sensible quantity. In the production of beer, the sugar is derived from the malt; in that of wine, from the juice of the grape.

1871. In the manufacture of *beer*, the malt is ground and infused in the *mash-tun*, in rather more than its bulk of water, of the temperature of 160° or 180°. Here the mixture is stirred for a few hours; the liquor is then run off, and more water added, until the malt is exhausted. These infusions are called *wort*, and its principal contents are *saccharine matter*, *starch*, *mucilage*, and a small quantity of *gluten*. The strength of the wort is adjusted by its specific gravity, which is usually found by an instrument not quite correctly called a *saccharometer*, since it is influenced by all the contents of the wort, and not by the sugar only. It is a brass instrument, of the shape shown in the margin, so adjusted in weight as to sink to the point marked 0°, in distilled water, at the temperature of 70°, and when immersed in a liquor of the same temperature, and of the specific gravity of 1.100, it is buoyed up to the mark 100, just above the bulb. The intermediate space is divided into 100 equal parts, and consequently will indicate intermediate degrees of specific gravity. This is the most useful form of the instrument, though not that in common use. The specific gravity of the wort for ale is usually about 1.090 to 1.100, and for table-beer from 1.020 to 1.030.

Hydrometer.



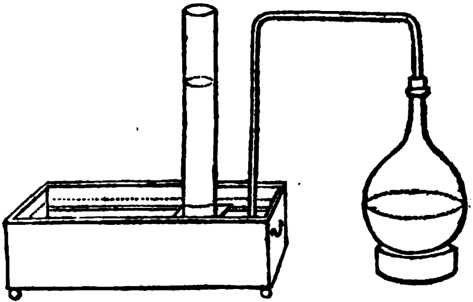
The wort is next boiled with hops, amounting upon the average, to $\frac{1}{36}$ the weight of the malt, their use being to cover the sweetness of the liquor by their aromatic bitter, and to diminish its tendency to acidify. The liquor is then thrown into large, but very shallow, vessels, or *coolers*, where it is cooled to about 50°, as quickly as possible; it is then suffered to run into the *fermenting vat*, having been previously mixed with a proper quantity of *yeast*, which accelerates fermentation, apparently by virtue of the gluten which it contains.

In the fermenting vessel, the different substances held in solution in the liquor begin to act upon each other; an intestine motion ensues, the temperature of the liquor increases, carbonic acid escapes in large quantities; at length this evolution of gas ceases, the liquor becomes quiet and clear, and it has now lost much of its sweetness, has diminished in specific gravity, acquired a new flavour, and become intoxicating.

1872. The distillers prepare a liquor, called *wash*, for the express purpose of producing from it ardent spirits; instead of brewing this from pure malt, they chiefly employ raw grain, mixed with a small quantity only of malted grain; the water employed in the mashtun is of a lower temperature than that requisite in brewing, and the mashing longer continued; by which it would appear that a part of the starch of the barley is rendered into a kind of saccharine matter. The wort is afterwards fermented with yeast.

1873. *Wine* is principally procured from the juice of the grape, and some other saccharine and mucilaginous juices of fruits. The principal substances held in solution in grape juice are, *sugar*, *gum*, *gluten*, and *bi-tartrate of potassa*. It easily ferments spontaneously at temperatures between 60° and 80°, and the phenomena it gives rise to closely resemble those of the wort with yeast. After the operation, its specific gravity is much diminished, its flavour changed, and it has acquired intoxicating powers.

1874. If a mixture of 1 part of sugar, 4 or 5 of water, and a little yeast, be placed in a due temperature, it also soon begins to ferment, and gives rise to the same products as wort or grape-juice; and, as the free admission of air is not necessary to vinous fermentation, its results may easily be examined by suffering the process to go on in the following apparatus; consisting of a matrass containing the fermenting mixture, with a bent tube issuing from it, and passing into an inverted jar standing in water.



Gaseous products of fermentation.

It will thus be found that the only gaseous product is carbonic acid: and consequently, that carbon and oxygen are the principles which the saccharine matter loses during the process.

1875. When any of the above-mentioned fermented liquors are distilled, they afford a *spirituous liquor*; that from wine is termed *brandy*; from the fermented juice of the sugar-cane we obtain *rum*; and from wash, *malt spirit*; and these spirituous liquors, by re-distillation, furnish *spirit of wine*, *ardent spirit*, or *alcohol*.

1876. The different fermented liquors furnish very different proportions of alcohol, and it has been sometimes supposed that it does not pre-exist to the amount in which it is obtained by distillation; but some experiments which I made upon the subject, in 1811 and 1813, and which are printed in the *Philosophical Transactions* for those years, tend to show that it is a real educt, and not formed by the action of heat upon the elements existing in the fermented liquor. The following Table exhibits the proportion of alcohol, specific gravity .825 at 60°, by measure, existing in 100 parts of several kinds of wine and other liquors:

	Proportion of Spirit per cent. by measure.
1. Lissa	26.47
Ditto	24.35
Average	25.41
2. Raisin wine	26.40
Ditto	25.77
Ditto	23.20
Average	25.12
3. Marsala	26.03
Ditto	25.05
Average	25.09
4. Port	25.83
Ditto	24.29
Ditto	23.71
Ditto	23.39
Ditto	22.30
Ditto	21.40
Ditto	19.00
Average	22.96
5. Madeira	24.42
Ditto	23 93
Ditto (Sercial)	21.40
Ditto	19.24
Average	22.27
6. Currant wine	20.55

	Proportions of Spirit per cent. by measure.
7. Sherry	19.81
Ditto	19.83
Ditto	18.79
Ditto	18.25
Average	19.17
8. Teneriffe	19.79
9. Colares	19.75
10. Lachryma Christi	19.70
11. Constantia, white	19.75
12. Ditto, red	18.92
13. Lisbon	18.94
14. Malaga	18.94
15. Bucellas	18.49
16. Red Madeira	22.30
Ditto	18.40
Average	20.35
17. Cape Muschat	18.25
18. Cape Madeira	22.94
Ditto	20.50
Ditto	18.11
Average	20.51
19. Grape wine	18.11
20. Calcavella	19.20
Ditto	18.10
Average	18.65
21. Vidonia	19.25
22. Alba Flora	17.26
23. Malaga	17.26
24. White Hermitage	17.43
25. Rousillon	19.00
Ditto	17.26
Average	18.13
26. Claret	17.11
Ditto	16.32
Ditto	14.08
Ditto	12.91
Average	15.10
27. Zante	17.05
28. Malmsey Madeira	16.40
29. Lunel	15.52
30. Sheraaz	15.52
31. Syracuse	15.28
32. Sauterne	14.22
33. Burgundy	16.60

	Proportions of Spirit per cent. by measure.
Ditto	15.22
Ditto	14.53
Ditto	11.95
Average	14.57
34. Hock	14.37
Ditto	13.00
Ditto (old in cask)	8.88
Average	12.08
35. Nice	14.63
36. Barsac	13.86
37. Tent	13.30
38. Champagne (still)	13.80
Ditto (sparkling)	12.80
Ditto (red)	12.56
Ditto (ditto)	11.30
Average	12.61
39. Red Hermitage	12.32
40. Vin de Grave	13.94
Ditto	12.80
Average	13.37
41. Frontignac (Rivesalte)	12.79
42. Cote Rotie	12.32
43. Gooseberry wine	11.84
44. Orange wine—average of 6 samples made by a London manufacturer	11.26
45. Tokay	9.88
46. Elder wine	8.79
47. Cider, highest average	9.87
Ditto, lowest ditto	5.21
48. Perry, average of 4 samp.	7.26
49. Mead	7.32
50. Ale (Burton)	8.88
Ditto (Edinburgh)	6.20
Ditto (Dorchester)	5.56
Average	6.87
51. Brown Stout	6.80
52. London Porter (average)	4.20
53. Ditto small beer (ditto)	1.28
54. Brandy	53.39
55. Rum	53.68
56. Gin	51.60
57. Scotch Whiskey	54.32
58. Irish ditto	53.90

1877. The principle upon which the intoxicating properties of fermented liquors depends, and which exists in ardent spirits, is in its purest form called *alcohol*. It may be obtained by distilling the *rectified spirit of wine* of commerce, with one-fourth of its weight of dry and warm carbonate of potassa; about three-fourths may be drawn over. There are other substances which may be used as substitutes for the carbonate, especially muriate of lime.

1878. Alcohol thus obtained by slow and careful distillation, is a limpid, colourless liquid, of an agreeable smell, and a strong pungent flavour. Its specific gravity varies with its purity; the purest obtained by rectification over muriate of lime being 791; as it usually occurs it is .820 at 60°. If rendered as pure as possible by simple distillation, it can scarcely be obtained of a lower specific gravity than .825, at 60°.

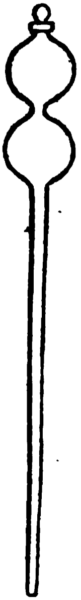
Alcohol.

1879. Alcohol has never been frozen, and consequently is particularly useful in the construction of thermometers intended to measure intense degrees of cold. When of a specific gravity of .825, it boils at the temperature of 176°, the barometrical pressure being 30 inches. In the vacuum of an air-pump it boils at common temperatures. The specific gravity of the vapour of alcohol, compared with atmospheric air, is 1.613.—GAY-LUSSAC, *Annales de Chimie et Phys.* Tom. i.

Condensation of Alcohol & water.

1880. Alcohol may be mixed in all proportions, with water, and the specific gravity of the mixture is greater than the mean of the two liquids, in consequence of a diminution of bulk that occurs on mixture as may be shown by the following experiment:

The annexed wood-cut represents a tube with two bulbs, communicating with each other, the upper one being supplied with a well-ground glass stopper. Fill the tube and lower bulb with water, pour alcohol slowly into the upper bulb, and when full put in the stopper. The vessel will now be completely filled, the alcohol lying upon the water; if it be inverted, the alcohol and water will slowly mix, and the condensation that ensues will be indicated by the empty space in the tube. A considerable rise of temperature takes place in this experiment, in consequence of the condensation.



1881. The strength of such spirituous liquors as consist of little else than water and alcohol, is of course ascertained by their specific gravity; and for the purpose of levying duties upon them, this is ascertained by the hydrometer; an instrument constructed upon the same principle as that described at page 520. But the only correct mode of ascertaining the specific gravity of liquids, is by weighing them in a delicate balance, against an equal volume of pure water, of a similar temperature (507).

1882. In the *Philosophical Transactions* for 1794, Mr. Gilpin has given a copious and valuable series of tables of the specific gravity of mixtures of alcohol and water, and of the condensation that ensues, with several other particulars. These are extremely useful, as enabling us to ascertain, without difficulty, the relative quantity of alcohol contained in any mixture of known specific gravity.

The original tables are extremely voluminous, and have been variously abridged by different persons; I have, however, thought it most useful to insert two of them, adapted to the temperature of 60°, and refer the reader to Mr. Gilpin's paper for those calculated at other temperatures.

TABLE

Of the Specific Gravity and Composition of Mixtures of Alcohol and Water at the Temperature of 60°.

I. Spirit and Water by Weight. Sp.+W.	II. Specific Gravity.	III. Spirit by Measure.	IV. Water by Measure.	V. Bulk of Mixture.	VI. Diminution of Bulk.	VII. Quantity of Spirit *per Cent.* by Measure.
100+ 0	.82500	100	—	100.00	—	100.00
1	.82731	—	0.83	100.72	0.11	99.29
2	.82957	—	1.65	101.44	0.21	98.58
3	.83177	—	2.47	102.16	0.31	97.88
4	.83391	—	3.30	102.89	0.41	97.19
100+ 5	.83599	—	4.12	103.62	0.50	96.51
6	.83802	—	4.95	104.35	0.60	95.83
7	.84001	—	5.77	105.09	0.68	95.16
8	.84195	—	6.60	105.83	0.77	94.50
9	.84384	—	7.42	106.57	0.85	93.84
100+10	.84568	—	8.25	107.31	0.94	93.19
11	.84748	—	9.07	108.05	1.02	92.55
12	.84924	—	9.90	108.80	1.10	91.91
13	.85096	—	10.72	109.55	1.17	91.28
14	.85265	—	11.55	110.30	1.25	90.66
100+15	.85430	—	12.37	111.05	1.32	90.04
16	.85592	—	13.20	111.81	1.39	89.44
17	.85750	—	14.02	112.56	1.46	88.84
18	.85906	—	14.85	113.32	1.53	88.25
19	.86058	—	15.67	114.08	1.59	87.66
100+20	.86208	—	16.50	114.84	1.66	87.08
21	.86355	—	17.32	115.60	1.72	86.51
22	.86500	—	18.15	116.36	1.79	85.94
23	.86642	—	18.97	117.12	1.85	85.38
24	.86781	—	19.80	117.88	1.92	84.83
100+25	.86918	—	20.62	118.64	1.98	84.28
26	.87052	—	21.45	119.41	2.04	83.74
27	.87183	—	22.27	120.18	2.09	83.21
28	.87314	—	23.10	120.94	2.16	82.68
29	.87442	—	23.92	121.71	2.21	82.16

I. Spirit and Water by Weight Sp.+W.	II. Specific Gravity.	III. Spirit by Measure.	IV. Water by Measure.	V. Bulk of Mixture.	VI. Diminution of Bulk.	VII. Quantity of Spirit *per Cent.* by Measure.
100+30	.87569	100	24.75	122.48	2.27	81.65
31	.87692	—	25.57	123.24	2.33	81.14
32	.87814	—	26.40	124.01	2.39	80.64
33	.87935	—	27.22	124.78	2.44	80.14
34	.88053	—	28.05	125.55	2.50	79.65
100+35	.88169	—	28.87	126.32	2.55	79.16
36	.88283	—	29.70	127.09	2.61	78.68
37	.88395	—	30.52	127.86	2.66	78.21
38	.88505	—	31.35	128.64	2.71	77.74
39	.88613	—	32.17	129.41	2.76	77.27
100+40	.88720	—	33.00	130.19	2.81	76.81
41	.88825	—	33.82	130.96	2.86	76.36
42	.88929	—	34.65	131.74	2.91	75.91
43	.89032	—	35.47	132.51	2.96	75.47
44	.89133	—	36.30	133.29	3.01	75.03
100+45	.89232	—	37.12	134.06	3.06	74.59
46	.89330	—	37.95	134.84	3.11	74.16
47	.89427	—	38.77	135.61	3.16	73.74
48	.89522	—	39.60	136.39	3.21	73.32
49	.89615	—	40.42	137.17	3.25	72.90
100+50	.89707	—	41.25	137.95	3.30	72.49
51	.89797	—	42.07	138.73	3.34	72.08
52	.89886	—	42.90	139.51	3.39	71.68
53	.89973	—	43.72	140.29	3.43	71.28
54	.90059	—	44.55	141.07	3.48	70.89
100+55	.90144	—	45.38	141.86	3.52	70.49
56	.90227	—	46.20	142.64	3.56	70.11
57	.90309	—	47.02	143.42	3.60	69.72
58	.90391	—	47.85	144.21	3.64	69.34
59	.90470	—	48.67	144.99	3.68	68.97
100+60	.90549	—	49.50	145.78	3.72	68.60
61	.90626	—	50.32	146.56	3.76	68.23
62	.90703	—	51.15	147.35	3.80	67.87
63	.90778	—	51.97	148.13	3.84	67.51
64	.90853	—	52.80	148.92	3.88	67.15

I. Spirit and Water by Weight. Sp.+W.	II. Specific Gravity.	III. Spirit by Measure.	IV. Water by Measure.	V. Bulk of Mixture.	VI. Diminution of Bulk.	VII. Quantity of Spirit *per Cent.* by Measure.
100+65	.90927	100	53.62	149.71	3.91	66.80
66	.91001	—	54.45	150.50	3.95	66.45
67	.91074	—	55.27	151.28	3.99	66.10
68	.91146	—	56.10	152.07	4.03	65.76
69	.91217	—	56.92	152.85	4.07	65.42
100+70	.91287	—	57.75	153.64	4.11	65.09
71	.91356	—	58.57	154.42	4.15	64.76
72	.91424	—	59.40	155.21	4.19	64.43
73	.91491	—	60.22	156.00	4.22	64.10
74	.91557	—	61.05	156.79	4.26	63.78
100+75	.91622	—	61.87	157.58	4.29	63.46
76	.91686	—	62.70	158.37	4.33	63.14
77	.91748	—	63.52	159.16	4.36	62.83
78	.91811	—	64.35	159.95	4.40	62.52
79	.91872	—	65.17	160.74	4.43	62.21
100+80	.91933	—	66.00	161.53	4.47	61.91
81	.91933	—	66.82	162.32	4.50	61.61
82	.92052	—	67.65	163.11	4.54	61.31
83	.92110	—	68.47	163.90	4.57	61.01
84	.92168	—	69.30	164.70	4.60	60.72
100+85	.92225	—	70.12	165.49	4.63	60.43
86	.92281	—	70.95	166.29	4.66	60.14
87	.92336	—	71.77	167.08	4.69	59.85
88	.92391	—	72.60	167.87	4.73	59.57
89	.92445	—	73.42	168.66	4.76	59.29
100+90	.92499	—	74.25	169.46	4.79	59.01
91	.92552	—	75.07	170.25	4.82	58.73
92	.92604	—	75.90	171.05	4.85	58.46
93	.92656	—	76.72	171.84	4.88	58.19
94	.92707	—	77.55	172.64	4.91	57.92
100+95	.92758	—	78.37	173.43	4.94	57.66
96	.92807	—	79.20	174.23	4.97	57.40
97	.92856	—	80.02	175.02	5.00	57.14
98	.92905	—	80.85	175.82	5.03	56.88
99	.92954	—	81.68	176.62	5.06	56.62

I. Water and Spirit by Weight. Sp.+W.	II. Specific Gravity.	III. Spirit by Measure.	IV. Water by Measure.	V. Bulk of Mixture.	VI. Diminution of Bulk.	VII. Quantity of Spirit *per Cent.* by Measure.
100+100	.93002	100	82.50	177.41	5.09	56.36
99	.93051	—	83.34	178.22	5.12	56.11
98	.93102	—	84.19	179.05	5.14	55.85
97	.93149	—	85.02	179.89	5.13	55.59
96	.93198	—	85.94	180.74	5.20	55.33
100+95	.93247	—	86.84	181.61	5.23	55.06
94	.93296	—	87.76	182.50	5.26	54.79
93	.93345	—	88.71	183.42	5.29	54.58
92	.93394	—	89.67	184.35	5.32	54.24
91	.93443	—	90.66	185.31	5.35	53.96
100+90	.93493	—	91.67	186.29	5.38	53.68
89	.93544	—	92.70	187.29	5.41	53.39
88	.93595	—	93.75	188.31	5.44	53.10
87	.93646	—	94.83	189.35	5.48	52.81
86	.93697	—	95.93	190.42	5.51	52.51
100+85	.93749	—	97.06	191.53	5.53	52.21
84	.93802	—	98.21	192.65	5.56	51.91
83	.93855	—	99.39	193.80	5.59	51.60
82	.93909	—	100.61	194.99	5.62	51.29
81	.93963	—	101.85	196.20	5.65	50.97
100+80	.94018	—	103.12	197.44	5.68	60.65
79	.94073	—	104.43	198.71	5.72	50.32
78	.94128	—	105.77	200.01	5.76	50.00
77	.94184	—	107.14	201.35	5.79	49.66
76	.94240	—	108.55	202.73	5.82	49.33
100+75	.94296	—	110.00	204.15	5.85	48.98
74	.94352	—	111.48	205.60	5.88	48.64
73	.94408	—	113.01	207.10	5.91	48.29
72	.94465	—	114.58	208.64	5.94	47.93
71	.94522	—	116.20	210.22	5.98	47.57
100+70	.94579	—	117.86	211.84	6.02	47.20
69	.94637	—	119.56	213.51	6.05	46.83
68	.94696	—	121.32	215.24	6.08	46.46
67	.94756	—	123.13	217.02	6.11	46.08
66	.94816	—	125.00	218.85	6.15	45.69

I. Water and Spirit by Weight. W. + Sp.	II. Specific Gravity.	III. Spirit by Measure.	IV. Water by Measure.	V. Bulk of Mixture	VI. Diminution of Bulk.	VII. Quantity of Spirit per Cent. by Measure.
100+65	.94876	100	126.92	220.74	6.18	45.30
64	.94936	—	128.90	222.69	6.21	44.91
63	.94997	—	130.95	224.70	6.25	44.50
62	.95058	—	133.06	226.78	6.28	44.10
61	.9511	—	135.25	228.93	6.32	43.68
100+60	.95181	—	137.50	231.14	6.36	43.26
59	.95243	—	139.82	233.44	6.38	42.84
58	.95305	—	142.23	235.82	6.41	42.41
57	.95368	—	144.73	238.28	6.45	41.97
56	.95430	—	147.32	240.82	6.50	41.52
100+55	.95493	—	150.00	243.47	6.53	41.07
54	.95555	—	152.77	246.22	6.55	40.61
53	.95617	—	155.65	249.08	6.57	40.15
52	.95679	—	158.65	252.05	6.60	39.67
51	.95741	—	161.77	255.14	6.63	39.19
100+50	.95804	—	165.00	258.34	6.66	38.71
49	.95867	—	168.37	261.68	6.69	38.21
48	.95931	—	171.87	265.16	6.71	37.71
47	.95995	—	175.53	268.80	6.73	37.20
46	.96058	—	179.35	272.59	6.76	36.68
100+45	.96122	—	183.34	276.56	6.78	36.16
44	.96185	—	187.50	280.70	6.80	35.63
43	.96248	—	191.86	285.05	6.81	35.08
42	.96311	—	196.43	289.60	6.88	34.53
41	.96374	—	201.21	294.38	6.88	33.97
100+40	.96437	—	206.25	299.42	6.83	33.40
39	.96500	—	211.54	304.71	6.83	32.82
38	.96563	—	217.10	310.28	6.82	32.23
37	.96626	—	222.97	316.15	6.82	31.63
36	.96689	—	229.17	322.36	6.81	31.02
109+35	.96752	—	235.71	328.90	6.81	30.40
34	.96816	—	242.65	335.84	6.81	29.78
33	.96880	—	250.00	343.21	6.79	29.14
32	.96944	—	257.81	351.04	6.77	28.49
31	.97009	—	266.13	359.38	6.75	27.83

I. Water and Spirit by Weight. W. + Sp.	II. Specific Gravity.	III. Spirit by Measure.	IV. Water by Measure.	V. Bulk of Mixture.	VI. Diminution of Bulk.	VII. Quantity of Spirit *per Cent.* by Measure.
100+30	.97074	100	275.00	368.28	6.72	27.15
29	.97139	—	284.48	377.79	6.69	26.47
28	.97206	—	294.64	387.99	6.65	25.77
27	.97273	—	305.56	398.95	6.61	25.07
26	.97340	—	317.31	410.74	6.57	24.35
100+25	.97410	—	330.00	423.48	6.52	23.61
24	.97479	—	343.75	437.29	6.46	22.87
23	.97550	—	358.70	452.31	6.39	22.11
22	.97622	—	375.00	468.64	6.36	21.34
21	.97696	—	392.86	486.58	6.28	20.55
100+20	.97771	—	412.50	506.29	6.21	19.75
19	.97848	—	434.21	528.08	6.13	18.94
18	.97926	—	458.33	552.29	6.04	18.11
17	.98006	—	485.29	579.34	5.95	17.26
16	.98090	—	515.62	609.76	5.86	16.40
100+15	.98176	—	550.00	644.25	5.75	15.52
14	.98264	—	589.29	683.66	5.63	14.63
13	.98356	—	634.61	729.10	5.51	13.72
12	.98452	—	687.50	782.11	5.39	12.79
11	.98551	—	750.00	844.74	5.26	11.84
100+10	.98654	—	825.00	919.87	5.13	10.87
9	.98761	—	916.67	1011.70	4.97	9.88
8	.98872	—	1031.25	1126.44	4.81	8.88
7	.98991	—	1178.57	1273.92	4.65	7.85
6	.99115	—	1375.00	1470.52	4.48	6.80
100+ 5	.99244	—	1650.00	1745.70	4.30	5.73
4	.99380	—	2062.50	2158.37	4.13	4.63
3	.99524	—	2750.00	2846.04	3.96	3.51
2	.99675	—	4125.00	4221.21	3.79	2.37
1	.99834	—	8250.00	8346.38	3.62	1.20

Strength. 1883. There are other methods of judging of the strength of spirituous liquors, which, though useful, are not accurate, such as the taste, the size and appearance of the bubbles when shaken, the sinking or floating of olive oil in it, and the appearances that it exhibits when burned; if it burns away perfectly to dryness, and inflames gunpowder or a piece of cotton immersed in it, it is considered as alcohol: the different spirituous liquors leave variable proportions of water when thus burned in a graduated vessel.

1884. There is the greatest difficulty in ascertaining what is meant by the term *proof spirit*. Dr. Thomson, quoting the Act of Parliament of 1762 (*System*, ii. 319), states, that at the temperature of 60°, the specific gravity of proof spirit should be 0.916; and he also observes, that *proof spirit* usually means a mixture of *equal bulks* of alcohol and water; but the specific gravity of such a mixture will, of course, depend upon that of the standard alcohol, which is not specified. *It appears* from GILPIN's *Tables*, that spirit of the specific gravity *.916* at 60°, consists *by weight*, of 100 parts of alcohol, specific gravity *.825*, at 60°, and 75 of water; and, *by measure*, of 100 parts of the same alcohol, and 61.87 of water. From the *Tables* of LOWITZ, quoted by Dr. Thomson, from CRELL's *Annals* (1796, i. 202), we learn, that equal weights of alcohol, specific gravity .796, at 60°, (and which may be regarded as *pure alcohol*,) and water, have a specific gravity of .917, which is very near legal proof, and which, according to GILPIN's *Tables*, contains 62.8 parts *per cent*. of his alcohol, *by measure*.

Properties of alcohol. 1885. Alcohol is extremely inflammable, and burns with a pale blue flame, scarcely visible in bright day-light. It occasions no fuliginous deposition upon substances held over it, and the products of its combustion are carbonic acid and water, the weight of the water considerably exceeding that of the alcohol consumed. According to Saussure, jun., 100 parts of alcohol afford, when burned, 136 parts of water, the production of which may be shown by substituting the flame of alcohol for that of water, in the apparatus described in the first of the work, under the Article WATER (236, i.), and if the tube at its extremity be turned down into a glass jar, it will be found that a current of carbonic acid passes out of it, which may be rendered evident by lime-water.

There are some substances which communicate colour to the flame of alcohol; from boracic acid it acquires a greenish yellow-tint; nitre and the soluble salts of baryta cause it to burn yellow, and those of strontia give it a beautiful rose colour; cupreous salts impart a fine green tinge.

1886. Alcohol dissolves pure soda and potassa, but it does not act upon their carbonates: consequently, if the latter be mixed with alcohol containing water, the liquor separates into two portions, the upper being alcohol deprived to a considerable extent, of water, and the lower the aqueous solution of the carbonate. The alcoholic solution of caustic potassa was known in old pharmacy, under the name of Van Helmont's *Tincture of Tartar*. Its use in purifying potassa has already been stated (544); if it be long kept it deposits small crystals of carbonate of potassa, and becomes nearly black, from the decomposition of a portion of alcohol. Ammonia and the carbonate are both soluble in alcohol; the greater number of the sulphates are insoluble in this menstruum, but it dissolves many of the muriates and nitrates. It also dissolves the greater number of the acids. It absorbs many gaseous bodies. It dissolves the vegetable acids, the volatile oils, the resins, tan, and extractive matter, and many of the soaps; the greater number of the fixed oils are taken up by it in small quantities only but some dissolve largely. It may be remarked, that many errors exist in the published estimates of the solubility of substances in alcohol, arising from the existence of water either in the solvent or substance dissolved.

1887. When the vapour of alcohol is passed through a red-hot copper tube, it is decomposed, a portion of charcoal is deposited, and a large quantity of carburetted hydrogen gas is evolved.

The most satisfactory experiments on the composition of alcohol are those of Saussure, as quoted by Dr. Thomson (*System*, ii. p. 327). He passed the alcohol through a red-hot porcelain tube, terminating in a glass tube six feet long and surrounded by ice; all the products were carefully collected and weighed. The result of this analysis was, that 100 parts of pure alcohol consist of

Hydrogen	13.70
Carbon	51.98
Oxygen	34.32
	100.00

These numbers approach to 3 proportionals of hydrogen = 3; 2 of carbon, = 12; and 1 of oxygen, = 8.

Or it may be regarded as composed of

Olefiant gas	61.63
Water	38.37
	100.00

If we consider it as composed of 1 volume of olefiant gas, and 1 volume of the vapour of water, the 2 volumes being condensed into 1, the specific gravity of the vapour of alcohol, compared with common air, will be 1.599, or, according to Gay-Lussac, 1.613.

1888. When alcohol is submitted to distillation, with certain acids, a peculiar compound is formed, called *ether*, the different ethers being distinguished by the name of the acid employed in their preparation.

a. SULPHURIC ETHER.

1889. *Sulphuric Ether* is the most important of these compounds; it is prepared as follows: Equal weights of alcohol and sulphuric acid are carefully mixed and introduced into a glass-retort placed in a sand-bath, to which is adapted a capacious tubulated glass globe, connected with a receiver, as represented in the wood-cut at page 92. Raise the mixture in the retort to its boiling point as rapidly as possible, and, keeping the receiver cool by water or ice, continue the distillation, till opaque vapours appear in the retort; then remove the receiver, and agitate its contents with a little quick-lime; after which pour off the clear liquor, and re-distil to the amount of three-fourths its original quantity with the same precautions as before. The ether may

Preparation.

be further purified by distilling it off muriate of lime. The *London Pharmacopœia* directs the distillation of ether with potassa, for its purification from sulphurous acid; and Mr. Richard Phillips, in his *Experimental Examination*, has given the following directions for procuring ether for pharmaceutical purposes, which answer extremely well. "Mix with 16 ounces of sulphuric acid, an equal weight of rectified spirit, and distil about 10 fluid ounces, add 8 ounces of spirit to the residuum in the retort, and distil about 9 fluid ounces; or continue the operation until the contents of the retort begin to rise or the product becomes considerably sulphurous; mix the two products, and if the mixture consist of a light and heavy fluid, separate them: add potash to the lighter, as long as it appears to be dissolved; separate the ether from the solution of potash, and distil about nine-tenths of it, to be preserved as *ether sulphuricus*, the specific gravity of which ought to be at most .750."

1890. Preparing ether upon a large scale, it is found that 14 parts of alcohol (specific gravity, .820) mixed with an equal weight of sulphuric acid (specific gravity 1.8,) and submitted to distillation, afford about 8 parts of impure ether (specific gravity .770). To the residuum 7 parts of alcohol may be added, and about 7¾ parts more of impure ether drawn off. These products, when mixed, have a specific gravity of about .782, and when rectified by distillation on carbonate of potassa, afford 10¼ parts of ether, of a specific gravity of .735, and about 3½ parts of ethereal spirit, which is employed instead of an equal quantity of alcohol in the next operation.

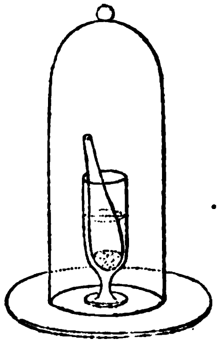
1891. When ether, obtained by the usual process, is washed with its bulk of water, its specific gravity is diminished, and the water employed for washing it affords, on distillation, a considerable portion of alcohol. By re-distilling this washed ether with a little potassa, which keeps down the water, or by treating it with muriate of lime, it is obtained extremely light and pure.

Properties. 1892. Sulphuric ether is a transparent, colourless liquid, of a pleasant smell and a pungent taste; it is highly exhilarating, and produces a degree of intoxication when its vapour is inhaled by the nostrils. Its specific gravity varies extremely with its purity. Lowitz is said to have procured it as light as .632. I have never obtained it lower than .700: and, as ordinarily prepared, its specific gravity varies between .730 and .760.

It is extremely volatile, and when poured from one vessel into another, a considerable portion evaporates; during its evaporation from surfaces, it produces intense cold, as may be felt by pouring it upon the hand; and seen, by dropping it upon the bulb of a thermometer, which sinks to many degrees below the freezing point (91). The specific gravity of the vapour of sulphuric ether, compared with atmospheric air, is, according to Gay-Lussac, as 2.586 to 1.000.

At mean pressure, sulphuric ether, when of a specific gravity of .720, boils at 98°, and under the exhausted receiver of the air-pump, at all temperatures above—20°; hence, were it not for atmospheric pressure, ether would only be known in the state of vapour.

In consequence of the cold produced during the vaporization of sulphuric ether, the phænomena of boiling and freezing may be exhibited in the same vessel. For this purpose procure a very thin flask which fits loosely into a wine-glass, as shown in the margin. Pour a small quantity of ether into the flask, and of water into the glass, and place the whole under the receiver of an air-pump; during exhaustion, the ether will boil, and a crust of ice will gradually form upon the exterior of the flask.



When subjected to a degree of cold equal to —46°, sulphuric ether freezes.

1893. Ether dissolves the resins, several of the fixed oils, and nearly all the volatile oils; it also dissolves a portion of sulphur, and of phosphorus; the latter solution is beautifully luminous when poured upon warm water, in a dark room. The fixed alcalis are not soluble in ether, but it combines with ammonia.

Ether dissolves the oxides of gold and platinum, and these solutions have been employed for coating steel with those metals, with a view to ornament and as a defence from rust. If to a saturated solution of gold or platinum, in nitro-muriatic acid, there be added about 3 parts by measure of good sulphuric ether, it soon takes up the metals, leaving the acid nearly colourless below the ethereal solution, which is to be carefully decanted off; into this the polished steel is for an instant plunged, and immediately afterwards washed in water, or in a weak alcaline solution. Though the coating of platinum is the least beautiful, Mr. Stodart, who has made many experiments upon this subject, considers it as the best protection from rust. Polished brass may be coated by the same process. These surfaces of gold and platinum, though very thin, are often a useful protection: with gold the experiment is particularly beautiful, and well illustrates the astonishing divisibility of the metal. The ethereal solution of gold is not permanent, but, after a time, deposits the metal in the form of a film, in which crystals of gold are often perceptible.

1894. Ether is sparingly soluble in water, and in alcohol it dissolves in all proportions. The *spiritus ætheris sulphurici* of the *Pharmacopœia*, is an alcoholic solution of ether.

1895. Ether is highly inflammable, and in consequence of its volatility it is often kindled by the mere approach of a burning body; a circumstance which renders it highly dangerous to decant, or open vessels of ether near a candle.

The inflammability of ethereal vapour may be shown by passing a small quantity into a receiver, furnished with a brass stop-cock and pipe, and inverted over water at the temperature of 100°. The receiver becomes filled with the vapour, which may be propelled and inflamed; it burns with a bright bluish white flame.

1896. When ether is admitted to any gaseous body it increases its bulk. Oxygen thus expanded, produces a highly inflammable mixture; if the quantity of oxygen be large, and of ether small, the mixture is highly explosive, and produces water and carbonic acid.

1897. When the vapour of ether is passed through a red-hot tube, it is decomposed, and furnishes a large quantity of carburetted hydrogen gas. Its analysis has been performed in various ways; M. Saussure, by detonating ethereal vapour with oxygen, and ascertaining the Ultimate analysis.

quantity of carbonic acid formed, and that of oxygen consumed, is led to consider the component parts of ether as,

Hydrogen - - - - - - -	14.40
Carbon - - - - - - - -	67.98
Oxygen - - - - - - - -	17.62
	100.00

which proportions are equivalent to

Olefiant gas - - - - - - -	100
Water - - - - - - - -	25

Or, it may be stated as consisting of

5	proportionals of olefiant gas,	7 × 5	= 35
1	,, water ,,		= 9
			44

which numbers, reduced to ultimate components, give

6	proportionals of hydrogen . .	1 × 6	= 6.
5	,, carbon . .	6 × 5	= 30
1	,, oxygen . .	———	= 8
			44

Rationale of etherification

1898. By reverting to the composition of alcohol, the change effected upon it by the sulphuric acid in the process of etherification will be evident, as also the rationale of the production of olefiant gas (421). Alcohol consists of

Olefiant gas	100
Water	50

If we now remove the whole of the water, which may be effected by a due proportion of sulphuric acid, we obtain olefiant gas only; but, if we only abstract half the water, we convert the alcohol into ether; not that either of these conversions are ever perfectly performed in any of our processes.

1899. When a little ether is introduced into chlorine, the gas is absorbed, and a peculiar compound results, in which muriatic acid is very perceptible; if the ether be inflamed, a large quantity of charcoal is deposited, and muriatic acid gas is abundantly evolved.

1900. If ether be mixed with its bulk of sulphuric acid, and submitted to distillation, a portion of it is converted into a peculiar fluid, which has been termed *oil of wine*; it is the *oleum æthereum* of the *Pharmacopœia*. It has a sweetish taste, and a rich agreeable odour. It does not mix with water, but readily dissolves in ether and in alcohol. It is very inflammable, and deposits a large quantity of carbon during its combustion. Its composition has not been inquired into.

1901. The residue of the distillation of ether has been examined by several chemists. According to Sertuerner, new acid compounds are produced, which he calls *œnothionic acids*. (THOMSON'S *Annals*, xiv. 44.) M. Vogel, in repeating these experiments, allows the formation of one new acid only, which he calls *sulphovinous acid*; he obtained it by saturating the residue of the distillation of ether with carbonate of lead; the liquor being filtered, contained a soluble *sulphovinate of lead;* sulphuretted hydrogen passed through this solution precipitated the lead and left the pure acid, which is so easily decomposed by heat as only to admit of concentration by evaporation under the exhausted receiver.

1902. *Sulphovinate of Baryta* was obtained by Gay-Lussac, in rhomboidal prisms terminated by a rhomboidal pyramid; the crystals were transparent, and permanent, but easily decomposed by heat.

1903. A strong analogy appears to subsist between the hyposulphuric and sulphovinous acids; and it will probably be found that the latter derives its peculiarities from the combination of a portion of ethereal oil.—*Annales de Chimie*, xiii. *Quarterly Journal of Science and Arts*, ix. 397.

1904. When ether is passed over red-hot platinum wire, or consumed in the lamp without flame, described in the chapter on Radiant Matter (191), a peculiar acid substance is produced, which has been subjected to an interesting series of experiments, by Mr. J. F. Daniell, (*Quarterly Journal of Science and Arts*, vi. 318.) He obtained it by placing the lamp, filled with ether, and properly trimmed with a coil of glowing platinum wire, under the head of an alembic, in which the vapour was condensed, and collected in a phial applied to its beak.

Lampic acid, for so Mr. Daniell has termed this product, is colourless, sour, and pungent; its vapour is very irritating, and its specific gravity, when purified by carefully driving off a portion of alcohol which it contains, is about 1.015. It reddens vegetable blues, and decomposes the alcaline carbonates with effervescence.

Mr. Daniell has described many of the combinations of this acid, which he terms *lampates*, and has given some experiments upon its composition, whence he deduces its ultimate components, as follow:

1	proportional carbon	6
1	——— hydrogen . . .	1
1	——— water	9
		16

When lampic acid is added to the solutions of silver, gold, platinum, mercury, and copper, and the mixture heated, the metals are thrown down in the metallic state.

On distilling the *lampate of mercury*, made by digesting the peroxide of mercury in the acid, Mr. Daniell obtained the concentrated or pure lampic acid, in the form of a very dense liquid with an intensely suffocating odour.

b. NITRIC ETHER.

1905. When strong nitric acid and alcohol are mixed in equal proportions, a violent action presently ensues; there is a very copious evolution of an inflammable aëriform body, which has been called *nitrous etherized gas*, and which appears to be a compound of nitrous ether, and nitric oxide. If we endeavour to condense the volatile products, we find that the receiver contains alcohol, water, nitrous ether, nitrous acid, and acetic acid; and that the greater portion of the true ether has made its escape with the gaseous products. Thenard has paid much attention to this subject, and has given the following process for obtaining nitric ether (*Mémoires d' Arcueil*, Tom. i., and *Traité de Chimie*, Tom. iii., p. 278.):

Preparation. Introduce into a sufficiently capacious retort equal weights of alcohol, (specific gravity 820) and of nitric acid of commerce (specific gravity 1.30) and connect it with five Wolfe's bottles, the first of which is empty, and the remaining four half-filled with a saturated solution of salt in water. Apply a gentle heat to the retort, till the liquor begins to effervesce; then withdraw the fire, and the gaseous matter passing through the bottles, which should be kept cold by ice, deposits the ether upon the saline solution, from which it is to be decanted, shaken with chalk, and re-distilled at a very gentle heat.

1906. Nitric ether, thus prepared, has the following properties: It has a very powerful ethereal odour; its colour is pale yellow; its taste very pungent; its specific gravity above that of alcohol, but less than that of water. It is more volatile than sulphuric ether, and the heat of the hand is sufficient to produce its ebullition. It is soluble in 48 parts of water; and in all proportions in alcohol; this last solution is the *spiritus ætheris nitrici*, or *sweet spirit of nitre*, of the *Pharmacopœia*. It is decomposed by keeping, and nitric and acetic acids are formed in it. According to Thenard, nitric ether consists of

Oxygen	48.52
Carbon	28.45
Nitrogen	14.49
Hydrogen	8.54
	100.00

Dr. Thomson (*System*, Vol. ii., p. 341.) concludes, from analogy, that nitric ether consists of 4 proportionals of olefiant gas, = 28, and 1 of nitric acid, = 54; or, of

4	proportionals of hydrogen	1 × 4 =	4
4	———— carbon	6 × 4 =	24
1	———— nitrogen	. . . .	14
5	———— oxygen	8 × 5 =	40
			82

1907. When nitric acid, holding mercury or silver in solution, is added to alcohol, a white precipitate is formed during the effervescence that ensues, which is possessed of powerful detonating properties.

Fulminating Mercury was discovered by Mr. Howard who has given the following directions for its preparation: Dissolve 100 grains of mercury, in a measured ounce and a half of nitric acid, by the assistance of a gentle heat; pour this solution into two measured ounces of alcohol, previously put into an evaporating basin, and apply a gentle heat till an effervescence ensues; when this has ceased, pour the liquid off the precipitate which falls, collect it upon a filter, wash it with a small quantity of water, and dry it at a heat not exceeding 212°.

Fulminating mercury thus prepared is in the form of small crystalline grains, of a whitish yellow or pale grey colour. A few grains placed on a smooth anvil and struck with a hammer, detonate with a sharp stunning report; it also explodes by friction, heat, and electricity; and by the action of concentrated sulphuric acid, though with less noise.

Mr. Howard considers this powder as a compound of oxalate of mercury and nitrous etherized gas: Fourcroy, however, has shown that its composition varies a little, under different circumstances of preparing it.—HOWARD, *Phil. Trans.*, 1800.

1908. By a similar process nearly, a species of *fulminating silver* may be prepared. (DESCOTILS, NICHOLSON'S *Journal*, Vol. xviii.) Upon three drachms of powdered nitrate of silver, pour two ounces and a half of alcohol, and add seven drachms, by measure, of nitric acid. When the effervescence has nearly ceased add a little water, wash the precipitate, and dry it in the open air, secluded from light.—ACCUM'S *Chemical Amusement*, 3d edit., p. 102.

This very dangerous compound explodes upon slight friction, or when gently heated, or touched with sulphuric acid, and, upon the contact of a sharp piece of glass or rock crystal, it detonates even under water; an electric spark also occasions its explosion.

When exploded under slight pressure in contact of gunpowder, it inflames it.

The composition of this species of fulminating silver has not been ascertained with precision; indeed, the subject is one of extreme difficulty, in consequence of the new products that are formed by its sudden decomposition.

c. MURIATIC ETHER.

1909. Muriatic ether was thus obtained by Thenard, (*Mémoirs d' Arcueil*, Tom. i.): Equal measures of strong liquid muriatic acid, and highly rectified alcohol, are put into a retort communicating with a receiver, from which a tube passes into a Wolfe's bottle containing warm water, and having a tube of safety: from this there issues a bent tube passing into a bottle surrounded by ice. On applying heat to the retort, a portion of alcohol and acid pass into the first receiver, and the ether in a gaseous state escapes through the warm water and the bent tube, and is condensed in the cold vessel. Preparation.

1910. At a temperature somewhat below 70° muriatic ether passes into the state of vapour, of which the specific gravity is about 2.220, that of air being 1.000; it is highly inflammable, its taste sweetish and ethereal, and it is soluble in its own bulk of water at 64°. Its specific gravity in a liquid state, at 40°, is .870. It is remarkable that this ether does not affect vegetable blues, nor does it afford traces of chlorine to the usual tests; but, when burned, muriatic acid is immediately perceptible.

1911. According to Thenard, this ether, contains

Muriatic acid	29.44
Carbon	36 61
Oxygen	23.31
Hydrogen	10.64
	100.00

Dr. Thomson considers muriatic ether as a compound of four proportionals of olefiant gas, and one of muriatic acid; hence it would contain

5	proportionals of hydrogen	1 × 5 =	5.
4	———— carbon	6 × 4 =	24.
1	———— chlorine	. . . .	36
			65

d. Hydriodic Ether.

1912. By distilling two measures of alcohol, with one of concentrated liquid hydriodic acid, Gay-Lussac obtained an ethereal liquid, of a specific gravity of 1.920 at 72°, and requiring a temperature of 148° for its ebullition. Its properties have not been very satisfactorily investigated, nor have any accurate experiments demonstrated its composition.—*Annales de Chimie*, xci.

Acetous Fermentation.

1913. When any of the vinous liquors are exposed to the free access of atmospheric air at a temperature of 80° or 85°, they undergo a second fermentation, terminating in the production of a sour liquid, called *vinegar*. During this process a portion of the oxygen of the air is converted into carbonic acid; hence, unlike vinous fermentation, the contact of the atmosphere is necessary, and the most obvious phænomenon is the removal of carbon from the beer or wine; the vinegar of this country is usually obtained from malt liquor, while wine is employed as its source in those countries where the grape is abundantly cultivated.

1914. The colour of vinegar varies according to materials from which it has been obtained; that manufactured in England is generally artificially coloured with burnt sugar: its taste and smell are agreeably acid. Its specific gravity is liable to much variation; it seldom exceeds 1.0250. When exposed to the air it becomes mouldy and putrid, chiefly in consequence of the mucilage which it contains, and from which it may be in some measure purified by careful distillation. According to Mr. R. Phillips, (*Remarks on the London Pharmacopœia*,) when good malt vinegar of the specific gravity of 1.020 is distilled, the first eighth that passes over is of the specific gravity 0.997; the next six-eighths are of specific gravity 1.0023, and a fluid ounce decomposes 8.12 grains of precipitated carbonate of lime. The lightness of the first portion is owing to its containing alcohol, consequently, in the *Pharmacopœia* process it is ordered to be rejected. The term *distilled vinegar*, or *dilute acetic acid*, is properly applied to the second portion; it is erroneously called *acetic acid*, in the *Pharmacopœia*. The matter which remains in the still is empyreumatic, and generally contains some other vegetable acids: when the vinegar has been adulterated, which is not unfrequently the case, we sometimes find in it muriatic and sulphuric acids.

1915. Distilled vinegar is colourless, and of a flat acid taste; it consists essentially of the real acid diluted with water. To obtain acetic acid, or, as it has been sometimes called, *radical vinegar*, distilled vinegar may be saturated with some metallic oxide, and the acetate thus obtained, subsequently decomposed.

1916. Acetic acid is thus procured by distilling *acetate of copper*, or *crystallized verdigris*, in a glass retort heated gradually to redness: it requires re-distillation to free it from a little oxide of copper which passes over in the first instance. Acetic acid may also be obtained by distilling *acetate of soda* or *acetate of lead* with half its weight of sulphuric acid: or from a mixture of equal parts of sulphate of copper and acetate of lead; in these cases, the acid passes over at a moderate temperature.

1917. A considerable quantity of acetic acid is also now procured by the distillation of wood in the process of preparing charcoal for the manufacture of gunpowder. The liquor at first procured is usually termed *pyroligneous acid;* it is empyreumatic and impure, and several processes have been contrived to free it from tar and other matters which it contains. It may be saturated with chalk and evaporated, by which an impure acetate of lime will be obtained, and which, mixed with sulphate of soda, furnishes, by double decomposition, sulphate of lime and acetate of soda: the latter distilled with sulphuric acid affords a sufficiently pure acetic acid, which by dilution with water may be reduced to any required strength. The purification of this acid has been brought to great perfection by Dr. Bollman.

1918. Acetic acid obtained by these processes is transparent and colourless, its odour highly pungent and it blisters and excoriates when applied to the skin. Its specific gravity is 1.080. It is extremely volatile, and its vapour readily burns. It combines in all proportions with water, and when considerably diluted, resembles distilled vinegar. When highly concentrated, it crystallizes at the temperature of 40°, but liquefies when its heat is a little above that point.

1919. According to Berzelius, whose analysis of acetic acid was very carefully conducted, (THOMSON'S *Annals*, Vol. iv.) its ultimate components are

Carbon	46.83
Oxygen	46.82
Hydrogen	6.35
	100.00

These numbers reduced to definite proportionals, are

3 proportionals of hydrogen $1 \times 3 = 3$
4 ——————— carbon $6 \times 4 = 24$
3 ——————— oxygen $8 \times 3 = 24$
51

Hence we see that there is no excess of oxygen in acetic acid, but that it consists of

3 proportionals of water $9 \times 3 = 27$
4 ——————— carbon $6 \times 4 = 24$
51

The chemist above quoted has given the composition of acetate of lead, at 100 acid + 217.5 oxide of lead, and

$$217.5 : 100 :: 112 : 51.4$$

so that the number 51.5 may safely be adopted as the representative of acetic acid.

1920. The acetates are all soluble in water, and mostly very soluble: many of them are deliquescent, and difficultly crystallizable; they are decomposed by sulphuric acid, and when submitted to destructive distillation, furnish a modified vinegar, which has been termed *pyroacetic acid* or *spirit*: these decompositions have been fully investigated, and the properties of the pyroacetic spirit inquired into, by Mr. Chenevix.—*Annales de Chimie*, xlix.

The following are among the most important of the acetates:

1921. *Acetate of Ammonia* is a very deliquescent, soluble salt, and extremely difficultly crystallizable. In solution, obtained by saturating distilled vinegar with carbonate of ammonia, it constitutes the *liquor ammoniæ acetatis* of the *Pharmacopœia*, which has long been used in medicine as a diaphoretic, under the name of *spirit of Mindererus.*

1922. *Acetate of Potassa* is usually formed by saturating distilled vinegar with carbonate of potassa, and evaporating to dryness. If this salt be carefully fused, it concretes into a lamellar deliquescent mass on cooling. It is the *terra foliata tartari*, and *febrifuge salt of Sylvius* of old pharmacy. It dissolves in its own weight of water at 60°, and the solution has an acrid saline taste. It consists of one proportional of each of its components, or 48 potassa + 51.5 acetic acid = 99.5 acetate of potassa.

1923. *Acetate of Soda* forms prismatic crystals, not deliquescent, of an acrid bitterish taste, and soluble in rather less than three parts of water at 60°. It is the *terra foliata crystallisata* of old writers. It consists of 32. soda + 51.5 acetic acid.

1924. *Acetate of Lime*, is a difficultly crystallizable salt, readily soluble in water, and of a bitter saline taste; consisting of 28 lime + 51.5 acid. It is sometimes obtained by saturating the vinegar formed during the distillation of wood, and employed in the preparation of *acetate of alumina*, which is used by the calico-printers as a mordant.

1925. *Acetate of Baryta* furnishes acicular crystals of a sour and bitterish taste: in cold weather the concentrated solution congeals into a silky congeries of crystals. It requires rather more than its own weight of water at 60° for solution, and consists of 51.5 acid + 78. baryta.

1926. *Acetate of Strontia* furnishes small permanent crystals, consisting of 51.5 acid + 52 strontia.

1927. *Acetate of Magnesia* is uncrystallizable, and of a bitterish sweet taste. It consists of 51.5 acid + 20 magnesia.

1928. *Acetate of Manganese*, formed by dissolving the protocarbonate in acetic acid, crystallizes in rhomboidal tables, permanent, and of a reddish colour and astringent metallic taste, soluble in 3½ parts of water at 60°. They consist of 70 acid and water + 30 protoxide of manganese.—John, Gehlen's *Journal*. iv.

1929. *Acetate of Iron*. The acetic acid combines with both oxides of iron. The *protacetate* is formed by digesting sulphuret of iron in acetic acid; it yields green prismatic crystals, of a styptic taste, and readily soluble in water; the solution becomes brown by exposure to air, and passes into *peracetate*, which is uncrystallizable, and obtained by digesting iron in acetic acid. This compound is extensively used by calico-printers, who prepare it either by digesting iron in pyrolig neous acid, or by mixing solution of acetate of lead with sulphate of iron, and exposing the filtered solution to air.

1930. *Acetate of Zinc* is formed either by dissolving oxide of zinc in acetic acid, or by mixing a solution of sulphate of zinc with one of acetate of lead. It crystallizes in thin shining plates of a bitter and metallic taste, very soluble, but not deliquescent. This salt is sometimes used in pharmacy, chiefly as an external application. According to Messrs. Aikin, the specific gravity of a saturated solution of acetate of zinc, made my digesting the salt in distilled vinegar, is 1055. Of this solution 900 grains contain 53 of dry, or 82.6 of crystallized acetate. One ounce by measure of the solution weighs 506 grains, and contains 29.8 grains of dry, or 46.5 grains of crystallized salt.

1931. *Acetate of Tin.* This metal is slowly acted on by acetic acid, but a *protacetate* and *peracetate of tin* may be made by mixing acetate of lead with saturated solutions of the protomuriate and permuriate of tin. These solutions have been recommended as mordants for the use of dyers. The protacetate is crystallizable. Vinegar kept in tin vessels dissolves a very minute portion of the metal; and in pewter vessels it likewise dissolves a small portion of the lead, where in contact both with the vinegar and air; hence distilled vinegar, which has been condensed in a pewter worm, affords generally traces of both metals.—VAUQUELIN, *Annales de Chimie*, xxxii.

1932. *Acetate of Copper.* By exposing copper to the fumes of vinegar, it becomes gradually incrusted with a green powder called *verdigris*, which is separable by the action of water, into an insoluble *subacetate of copper*, and a soluble *acetate.*

Acetate of copper may be obtained by digesting verdigris, or oxide of copper, in acetic acid; by evaporating this solution, it is obtained in prismatic crystals of a fine green tint. It dissolves sparingly in water and alcohol, and communicates a beautiful blue-green colour to the flame of the latter; by distillation it affords a very pure acetic acid. According to Dr. Thomson, acetate of copper, in its crystallized state, consists of

1	proportional of acid	51.5
1	———— oxide of copper . . .	72.
8	———— water	72.
		195.5

1933. *Acetate of Lead*, is the *sugar of lead*, and *salt of Saturn* of the old chemists: it may be regarded as the most important of the acetates; it is used in pharmacy, and by dyers and calico-printers for the preparation of acetate of alumina and of iron, which are formed by mixing its solution with that of the sulphates of those metals, an insoluble sulphate of lead being at the same time produced. Acetate of lead is formed by digesting the carbonate in distilled vinegar, or in the acetic acid obtained by the destructive distillation of wood; it usually occurs in masses composed of acicular crystals; but by careful crystallization it may be obtained in quadrangular prisms. Its taste is sweet and astringent, and it is soluble in about four parts of water at 60°. It is sometimes improperly termed a *superacetate*, but the salt is neutral, though when dissolved in water containing the smallest portion of carbonic acid, a white insoluble compound of lead falls, and a little acetic acid being liberated, the solution is rendered sour.

Carbonic acid passed through a solution of acetate of lead, precipitates, as I am informed by Mr. James South, exactly half the quantity of the oxide which the salt contains; hence a *binacetate* is probably formed which however does not afford crystals.

According to the experiments of Berzelius, acetate of lead consists of

Acetic acid	26.97
Protoxide of lead	58.71
Water	14.32
	100

hence the dry acetate is composed of

1	proportional of acetic acid	51.5
1	———— yellow oxide of lead . . .	112.
		163.5

When acetate of lead is submitted to destructive distillation it furnishes a considerable quantity of a peculiar fluid, smelling and burning like alcohol.—Proust, *Journal de Physique*, Tom. lvi.

1934. When 100 parts of sugar of lead are boiled in water with about 150 of yellow oxide, or of finely powdered litharge, a salt is obtained which crystallizes in plates, and is less sweet and soluble than the acetate; it has been termed *subacetate of lead*, and consists according to Berzelius of 1 proportional of acid = 51.5 + 3 proportionals of oxide of lead 336. This compound has long been used in pharmacy, under the name of *Goulard's extract of lead*. It is very rapidly precipitated by carbonic acid, of which it is a most delicate test; it also has a strong attraction for vegetable colouring matter, upon which principle I employed it in my analysis of wines.—*Phil. Trans.*, 1813.

1935. *Acetate of Antimony*, formed by digesting the protoxide in acetic acid, was once employed as an emetic.

1936. *Acetate of Bismuth* may be formed by adding nitrate of bismuth to a concentrated solution of acetate of potassa; a precipitate falls, which re-dissolves on the application of heat, and afterwards affords scaly crystals. The addition of acetic acid to nitrate of bismuth prevents its precipitation when diluted.—Morveau, *Encycl. Method. Chimie*, i. 10.

1937. *Acetate of Cobalt* may be obtained by digesting oxide of cobalt in acetic acid; it is uncrystallizable, and furnishes a sympathetic ink, colourless when cold, but blue when heated.

1938. *Acetate of Uranium* forms four-sided prismatic crystals of a yellow colour.

1939, *Acetate of Titanium*, not examined.

1940. *Acetate of Cerium*. Recently precipitated oxide of cerium readily dissolves in acetic acid, and yields small crystals on evaporation, of a sweetish taste, permanent, and readily soluble in water.—Hisinger and Berzelius, Gehlen's *Journal*, ii. 414.

1941. *Acetate of Nickel* forms green rhomboidal crystals.

1942. *Acetate of Mercury*. *Protacetate of Mercury* is most readily formed by mixing a solution of protonitrate of mercury with acetate of potassa. For this purpose dissolve three ounces of mercury in about four ounces and a half of cold nitric acid, and mix this solution with three ounces of acetate of potassa previously dissolved in eight pints of boiling water, and set the whole aside to crystallize, which takes place as the liquor cools, and the acetate of mercury then separates in the form of micaceous crystalline plates, which are to be washed in cold water, and dried on blotting paper. (*Edinburgh Pharmacopœia.*) In preparing this salt, the quantity of water for dissolving the acetate need not be so large as above directed, one pint being sufficient, but it is necessary to pour the mercurial solution into the acetate. This salt has an acrid taste, and is very difficultly soluble in water, requiring, according to Braconnot, (*Annales de Chimie*, lxxxvi. 92.) 600 parts of water. It is insoluble in alcohol. It was once used in medicine.

1943 *Peracetate of Mercury* is formed by digesting the peroxide in acetic acid; it does not crystallize, and affords on evaporation a deliquescent yellow mass, which is decomposed by water into a *superperacetate*, which remains dissolved; and an insoluble *subperacetate*.—PROUST, *Journal de Phys.*, lvi.

1944. *Acetate of Silver* is obtained by boiling the acid on oxide of silver, or by mixing solutions of acetate of potassa and nitrate of silver; it forms acicular crystals of an acrid metallic taste.

1945. *Acetate of Alumina.* This salt is extensively employed by calico-printers as a mordant or basis for fixing colours; they produce it by mixing solutions of alum and acetate of lead: about three pounds of alum are dissolved in eight gallons of water and a pound and a half of sugar of lead stirred into it; a copious formation of sulphate of lead ensues which is allowed to subside, and the clean liquor holding acetate of alumina and a portion of undecomposed alum in solution, is then drawn off, a portion of pearlash and chalk being added to it previous to use, in order to saturate any excess of acid.

Acetate of alumina, formed by digesting recently precipitated alumina in acetic acid, may be procured in deliquescent acicular crystals of an astringent taste, and containing, according to Richter, 73.81 acid + 26.19 alumina: hence it is probably a *binacetate*.

When acetic acid and alcohol are repeatedly distilled together, a portion of *acetic ether* is formed, which has a peculiar and agreeable taste and smell, and a specific gravity of about .860 at 60°. It boils at about 160°, is highly inflammable, and emits acetic acid among its products of combustion. This ether is directed in some of the foreign Pharmacopœiæ for medical use, and the following is perhaps the best process for its production. Introduce into a tubulated retort 3 parts of acetate of potassa, 3 of alcohol, and 2 of sulphuric acid, and distil to dryness. To the product add one-fifth its weight of sulphuric acid, and draw off by a gentle heat a quantity of ether equal to that of the alcohol originally employed.

Acetic ether is much more soluble in water than sulphuric ether: according to M Thenard, water at 60° dissolves about a 7.5 part of its weight, and the solution is permanent. Caustic potassa decomposes it, and forms acetate of potassa.

Oxalic, citric, tartaric, and benzoic acids have been employed in the formation of ethers; the prescence of a mineral acid is indispensable to their formation.—URE's *Dictionary*, ART. *Ether*.

CHAPTER IX.

Of Animal Substances.

1946. The different sections of this chapter will contain an account of the ultimate and proximate principles of the substances belonging to the animal creation, of the different methods of analysis by which these principles are obtained, and of such of the animal functions as are concerned in their production, where these are susceptible of chemical elucidation.

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Section I. *Of the ultimate Principles of Animal Matter, and of the Products of its destructive Distillation.*

Nitrogen.

1947. The proximate principles of the animal creation consist, like those of vegetables, of a few elementary substances, which by combination in various proportions, give rise to their numerous varieties. Carbon, hydrogen, oxygen, and nitrogen, are the principal ultimate elements of animal matter; and phosphorus and sulphur are also often contained in it. The presence of nitrogen *constitutes the most striking* peculiarity of animal, compared with vegetable bodies; *but as some* vegetables contain nitrogen, so there are also certain animal *principles*, into the composition of which it does not enter.

Ammonia.

1948. The presence of nitrogen stamps a peculiarity upon the products obtained by the destructive distillation of animal matter, and which are characterized by the presence of ammonia, formed by the union of the hydrogen with the nitrogen. It is sometimes so abundantly generated as to be the leading product; thus, when horn, hoofs, or bones, are distilled *per se*, a quantity of solid carbonate of ammonia, and of the same substance combined with empyreumatic oil, and dissolved in water, are obtained; hence the pharmaceutical preparations called *spirit* and *salt of hartshorn*, and Dippel's *animal oil*. Occasionally the acetic, benzoic, and some other acids are formed by the operation of heat on animal bodies, and these are found united to the ammonia; cyanogen and hydrocyanic acid also frequently occur.

Carburetted hydrogen.

If the gas evolved during the decomposition of animal bodies be examined, it is generally inflammable, and consists of carburetted hydrogen, often with a little sulphuretted and phosphuretted hydrogen; carbonic oxide, carbonic acid, and nitrogen, are also sometimes detected in it.

The coal remaining in the retort is commonly very difficult of incineration, a circumstance depending upon the common salt and phosphate of lime, which it usually contains, forming a glaze upon its surface which defends the carbon from the action of the air. Animal charcoal is also found to be more effectual in destroying colour and smell, than that obtained from vegetables. (387.)

Putrefaction.

1949. By the term *putrefaction* we mean the changes which dead animal matter undergoes, and by which it is slowly resolved into new products. These changes require a due temperature, and the presence of moisture; for below the freezing point of water, or when perfectly dry, it undergoes no alteration.

During putrefaction the parts become soft and flabby, they change in colour, exhale a nauseous and disgusting odour, diminish considerably in weight, and afford several new products, some of which escape in a gaseous form, others run off in a liquid state, and others are contained in the fatty, or earthy residuum.

Antiseptics.

The presence of air, though not necessary to putrefaction, materially accelerates it, and those gases which contain no oxygen, are very efficient in checking or altogether preventing the process. Carbonic acid also remarkably retards putrefaction; and if boiled meat be carefully confined in vessels containing that gas, it remains for a very long time unchanged, as seen in M Appert's method of preserving meat.

There are several substances which, by forming new combinations with animal matter, retard or prevent putrefaction, such as many of the saline and metallic compounds; sugar, alcohol, volatile oils, acetic acid, and many other vegetable substances also stand in the list of antiputrefactives, though their mode of operating is by no means understood.

1950. The effluvia which arise from putrescent substances, and more especially those generated in certain putrid disorders, have a tendency to create peculiar diseases, or to give the living body a tendency to produce poisons analogous to themselves. An atmosphere thus tainted by infectious matter, may be rendered harmless by fumigation with the volatile acids, more especially the nitrous and the muriatic; chlorine is also very effectual: the vapour of vinegar, though sometimes useful in covering a bad smell, is not to be relied on. It appears evident that the acid and chlorine act chemically upon the pernicious matter, and resolve it into innocuous principles.

Adipocere.

1951. When muscular flesh is immersed in a stream of running water, it is partially converted into a substance having many of the properties of fat combined with a portion of ammonia. The same changes have been observed where large masses of putrefying animal matter have been heaped together, or where water has had occasional access to it. Nitrate of ammonia is also sometimes formed under the same circumstances.

1952. Instead of considering the proximate principles of animals under separate sections, as has been done in regard to vegetable bodies I shall make them known under the heads of those substances in which they occur, the principal of which are the following:

1. Blood. Albumen. Colouring Matter.
2. Milk. Sugar of Milk.
3. Bile. Resin of Bile.
4. Lymph. Mucus. Synovia, Pus, *&c.*
5. Urine. Urea. Urinary Calculi.
6. Skin. Membrane.
7. Muscle. Ligament. Horn. Hair.
8. Fat. Spermaceti, *&c.*
9. Cerebral substance.
10. Shell and Bone.

SECTION II. *Of the Blood.*

1953. IN the higher orders of animals the blood is of a red colour, florid in the arteries, and dingy in the veins. The specific gravity of human blood is liable to some variation. I have found it as low as 1.050 and as high as 1.070, but am unable to refer to any circumstances which might be considered as the cause of this difference.

When blood is drawn from its vessels in the living animal, it soon concretes into a jelly-like mass, which afterwards gradually separates into a fluid *serum*, of a pale straw colour, and a coagulated *crassamentum*, or *cruor*, which is red. The cause of this coagulation is quite unknown.

1954. The specific gravity of the serum of the blood, is upon an average 1.030. It reddens the yellow of turmeric, and changes the blue of violets to green, a property derived from a portion of soda. At a temperature of 160°, it becomes a firm yellowish white coagulum, resembling in appearance and properties the coagulated white of egg, and, as the principle to which this property is owing is the same in both substances, it has been called *albumen*. Alcohol, and many of the acids, also occasion the coagulation of the serum of blood.

100 parts of human serum contain between eight and nine parts of albumen, rather less than one part of carbonate of soda, and about the same quantity of common salt, the remaining 90 parts being water. These at least are the proportions which my own experiments lead me to believe correct; but the analysis is involved in so much difficulty that the results can only be considered as approximating to the truth; indeed it is probable that the composition of the serum is liable to much variation.

Dr. Marcet and Berzelius have each given an analysis of the serum of human blood; the following are their results. (*Medico-Chirurgical Transactions*, Vol. ii. *Annals of Philosophy*, Vol. ii.):

MARCET.

Water	900.
Albumen	86.8
Muriates of potassa and soda	6.6
Muco-extractive matter	4.0
Carbonate of soda	1.65
Sulphate of potassa	0.35
Earthy phosphates	0.60
	1000.00

BERZELIUS.

Water	905.0
Albumen	80.0
Muriates of potassa and soda	6.0
Lactate of soda, with animal matter	4.0
Soda and phosphate of soda with ditto	4.1
Loss	0.9
	1000.0

1955. *Albumen*, which constitutes a leading ingredient in the serum, and which we shall presently find also in the cruor, is a very important animal principle, and is found in the greater number of animal fluids and solids.

Liquid Albumen is soluble in water, and always contains a notable portion of soda, indicated by its action on vegetable colours. It is coagulated by heat, acids, and alcohol, unless it be considerably diluted with water, in which case a portion separates in the form of white flakes after some hours' standing. Solution of corrosive sublimate, added to albumen very much diluted, produces a cloudiness, and hence it is a useful test of albumen. (BOSTOCK, NICHOLSON'S *Journal*, xiv.) It is also instantly coagulated by Voltaic electricity; and if two platinum wires connected with a small battery be immersed into a diluted albumen, it will cause a very rapid coagulation at the negative pole, and scarcely any effect at the positive pole. This circumstance induced me to atribute the coagulation to the removal of the alcali, by alcohol, and by acids; but how heat operates is not very obvious, unless we be allowed to consider it as effecting a kind of decomposition of the liquid albumen. We might thus consider liquid albumen as a compound of albumen and soda dissolved in water: the effect of heat would then be to transfer the soda to the water, and thus occasion a coagulation; and a solution of soda is always found oozing from coagulated serum, and has sometimes been called *serosity*; in time it re-acts upon the coagulum, and dissolves a portion of it.

1956. When albumen is dried in a moderate heat, it shrinks and becomes brown and simi-transparent, resembling horn in appearance and properties. In this state it scarcely dissolves in boiling water, though it gradually softens; it is not prone to decomposition; it dissolves in the alcalis, a portion of ammonia being evolved and a saponaceous compound formed. Dilute nitric acid converts it into a substance having the properties of gelatine. (HATCHETT, *Phil. Trans.*, 1800.)

By destructive distillation albumen furnishes a variety of products characterized by the presence of a large proportion of ammonia. According to Gay-Lussac and Thenard, (*Recherches Physico-chymiques*) its ultimate constituents are

Carbon	52.883
Oxygen	23.872
Hydrogen	7.540
Nitrogen	15.705
	100.000

1957. When the coagulum of the blood is carefully washed under a small stream of water, the colouring matter is gradually dissolved, and washed out of it, and a white fibrous substance remains, which has been termed *fibrina* or *coagulable lymph*, but of which the chemical properties are those of albumen.

It sometimes happens, when the blood is long in coagulating, as in certain inflammatory diseases, that a portion of this albumen is left without the colouring matter, forming what has been called the *buffy coat of blood;* in this case it is so tough as to admit of being removed from the coloured portion, and when dried, shrinks up, and appears exactly like horn.

Although the cause of the spontaneous coagulation of blood be unknown, the process consists in a portion of the albumen separating in a solid form along with the colouring matter, while another portion remains dissolved in the serum; this effect is somewhat analogous to the crystallization of a saline solution, in which one portion of the salt separates, while another remains dissolved.

1958. The colour of the blood has generally been referred to small globules of a red colour, which by the aid of the microscope may be discerned in it; and it was supposed that these globules are soluble in water. But it has been shown by Dr. Young, that this is not the case, and that the effect of water is to dissolve the colouring matter only, leaving the globule perfectly colourless; in this state the globular particles have the properties of albumen. The diameter of the globules in human blood varies from $\frac{1}{5000}$ to $\frac{1}{6000}$ of an inch.—*Remarks on Blood and Pus, in* Dr. YOUNG's *Medical Literature.*

The colouring matter of the blood can scarcely be obtained free from other substances. By stirring it during coagulation, a considerable portion is diffused through the serum from which it afterwards subsides. Vauquelin advises the digestion of the coagulum, drained of serum, in dilute sulphuric acid, at a temperature of 160°. The liquid, filtered while hot, is to be evaporated to half its bulk, and nearly saturated with ammonia; the colouring matter falls, and is to be washed and dried, (*Annales de Chimie et Physique*, Tom. i.) We must not, however, trust animal principles to these complex operations; and there can I think be little doubt that the colouring principle has undergone some change in M. Vauquelin's process.

The chemical properties of the colouring matter of the blood show that it is a peculiar animal principle. It is soluble in *cold* water, and the solution, when boiled, deposits a brown sediment of altered colouring matter. Muriatic, dilute sulphuric, and several of the vegetable acids, and the caustic and carbonated alcalis, readily dissolve the colouring matter, and form solutions of different tints of red, and of a peculiar greenish hue when viewed by transmitted light. Nitric acid instantly renders these solutions brown, and decomposes the red principle. These experiments, of which I have given a detailed account in the *Philososophical Transactions* for 1812, led me to regard the colouring matter of the blood as a distinct proximate principle of animal matter, perfectly independent of the presence of iron, to which its peculiarities were at one time referred by MM. Fourcroy and Vauquelin; and the latter of these celebrated chemists has more lately verified my conclusions in the above-quoted memoir. Berzelius, whose labours in animal chemistry are so extended and well known, has, however, obtained different results; he finds the crassamentum of the blood to consist of

Colouring matter	64
Fibrin and albumen	36
	100

The colouring matter, when incinerated, affords a residue, consisting of

Oxide of iron	50.0
Subphosphate of iron	7.5
Phosphate of lime with magnesia	6.0
Lime	20.0
Carbonic acid and loss	16.5
	100.0

The iron appears to be regarded by Berzelius as contributing to the red colour of the blood, (THOMSON'S *System*, Vol. iv.; p. 501.) a conclusion which my own experiments, detailed in the paper already quoted, by no means warrant, and which is also at variance with the opinion of M. Vauquelin.

1959. Besides the principles now enumerated, and which may be considered as essential to the blood, it often contains carbonic acid, which escapes when the blood is gently heated, or placed under the exhausted receiver of the air-pump.

Experiments on the blood, in different diseases, have thrown no light whatever on their nature, nor have any material differences been found in the blood of the same animal at different periods, or in that of different animals of the same class.

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SECTION III. *Milk.*

1960. THE chemical properties of this secretion differ somewhat in different animals. The milk of the cow has been most attentively examined, and it has the following properties:

It is nearly opaque; white, or slightly yellow; of an agreeable sweetish taste, and a peculiar smell. Its specific gravity varies from 1018 to 1020. It boils at a temperature a little above that of water, and freezes at 32°. When allowed to remain a few hours at rest, a thick unctuous liquid collects upon its surface called *cream;* the colour of the remaining milk becomes bluish white and when heated to about 100° with a little *rennet*, it readily separates into a *coagulum* or *curd*, and a *serum* or *whey*. In this way the three principal constituents of milk are separable from each other.

1961. By the process of churning, cream is separated into *butter*, and *butter-milk*, the latter being the whey united to a portion of curd. According to Berzelius, 100 parts of cream, of the specific gravity of 1024, consists of

Butter	4.5
Curd	3.5
Whey	92.0
	100.0

Butter may be considered as an animal oil, containing a small portion of curd and whey. It liquefies at about 98°, and by this process the impurities are separated, and it remains a longer time without becoming rancid.

1962. The *curd* of milk has the leading properties of coagulated albumen, and, like that principle, is coagulable by alcohol and acids, and is also similarly affected by Voltaic electricity; heat slowly produces the same effect, and by boiling milk, the albumen separates in successive films.

1963. Curd, in combination with various proportions of butter, constitutes the varieties of *cheese;* that containing the largest quantity of oil becomes semi-fluid when heated; it is prone to decomposition, and a large quantity of ammonia is then formed in it; whereas bad cheese, which consists of little else than curd or albumen, shrinks and dries when heated, curling up like a piece of horn.

1964. *Whey* is a transparent fluid of a pale yellow colour and a sweetish flavour; by evaporation it affords a minute quantity of saline matter, and a considerable portion of sugar of milk.

1965. *Sugar of Milk* may be obtained in white rhomboidal *crystals*, of a sweet taste, and soluble in seven parts of water at 60°, but insoluble in alcohol. When exposed to heat, it affords nearly the same products as common sugar. It consists, according to Berzelius, when deprived of water, of

Carbon	45.267
Oxygen	48.348
Hydrogen	6.385
	100.000

1966. When sugar of milk is treated with nitric acid, it affords a peculiar acid, similar to that above-mentioned, as obtained from gum (1549). To procure this acid, one part of powdered gum arabic may be digested in two of nitric acid, in a moderate heat; as soon as effervescence commences, set the flask in a cool place, and a quantity of white powder subsides, which is to be collected upon a filter, digested in dilute nitric acid to separate oxalate of lime, and subsequently purified by boiling water, which deposits the *mucic* or *saclactic acid* on cooling. If sugar of milk be used instead of gum, it is obtained pure by the first operation. This acid is not crystallizable, and is sparingly soluble in water, requiring 60 parts at 212°, and is deposited as the solution cools, in the form of a white gritty powder, of a slightly acid taste. It combines with the metallic oxides, and forms a class of salts called *saccholates.* It consists, according to Berzelius, (*Annals of Philosophy*, Vol. v.) of

Carbon - - - - - - - -	33.430
Oxygen - - - - - - - -	61.465
Hydrogen - - - - - - - -	5.105
	100.000

1967. The *saccholates*, or *saclactates;* have scarcely been examined. With ammonia, potassa, and soda, this acid forms crystallizable compounds, more soluble than the acid. The saclactates of lime, baryta, and strontia, are insoluble, as are those of silver, mercury, and lead.

1968. When milk or whey are exposed to a temperature between 60° and 80°, they undergo a spontaneous change, attended by the production of an acid, which was originally examined by Scheele, and has been termed *lactic acid.* Fourcroy and Vauquelin have shown reason to suspect its peculiar nature, and were led to regard it as identical with the acetic acid. Berzelius has more recently revived the opinion of Scheele, but I am induced from my own experiments to believe, that if it be not the acetic acid originally, it becomes so by combination with a base, and subsequent separation by sulphuric acid.

1969. In some cases whey may be made to undergo vinous fermentation; and the Tartars, it is said, prepare a kind of wine from the whey of mares' milk, which they call *Koumiss.—Edinburgh Phil. Trans.*, Vol. ii.

SECTION IV. *Bile.*

1970. THIS secretion is formed in the liver, from venous blood. It is an unctuous liquid, of a yellowish green colour, and its specific gravity is between 1020 and 1030. Its taste is intensely bitter, and it readily putrefies, exhaling a most nauseous odour.

1971. When the bile of the ox is distilled, it affords about 90 *per cent.* of insipid water; the residuum is brown, bitter, and may be redissolved in water; it affords traces of uncombined alcali, which appears to be soda. The acids render bile turbid, and separate from it a substance which possesses many of the properties of albumen. It is likewise coagulated by alcohol, and upon filtering off the clear liquor and evaporating it, an inflammable fusible substance is obtained, of an intensely bitter flavour, combined with a portion of soda and common salt: this has been termed the *resin of bile*, and appears to be the principle which confers upon it its chief peculiarities. We should, therefore, conclude, as the result of these observations, that bile consists of water, albumen, soda, a bitter resin, and some minute portions of saline matter.

1972. Thenard separated from bile a peculiar substance, which he has termed *picromel;* but the process by which he obtained it is so complex, that I think it doubtful whether it be a product or an educt. The same chemist has given the following table of the ingredients of ox-bile, but as this secretion is liable to considerable variation in appearance and specific gravity, it is probable that little reliance can be placed in the accuracy of the numbers (*Traité de Chimie*, Tom. iii., p. 556.):

Water	700
Resin	15
Picromel	69
Yellow matter	4
Soda	4
Phosphate of soda	2
Muriates of soda and potassa	3.5
Sulphate of soda	0.8
Phosphate of lime and of magnesia	1.2
Oxide of iron	a trace
	1000.

1973. *Biliary Calculi* are of two kinds; those which most commonly occur, are soft, fusible, of a crystalline texture, and inflammable. They have generally been considered as closely resembling spermaceti; they are soluble in boiling alcohol, in ether, and difficultly in oil of turpentine. Chevreul, having remarked some peculiarities in this substance, is induced to regard it as a peculiar animal principle, and distinguishes it by the name of *cholesterine*.

1974. Cholesterine is fusible at 280°, and on cooling concretes into a crystalline mass; rapidly heated to about 400° it evaporates in dense smoke; it is insoluble in water, and nearly so in cold alcohol; boiling alcohol dissolves about $\frac{1}{18}$ its weight. It is soluble in nitric acid; but not convertible into soap by the alcalis.

1975. The other kind of biliary calculus resembles inspissated bile in appearance, but differs from it in being insoluble in alcohol and water. It is often mixed with variable proportions of the former, constituting biliary calculi of intermediate characters.

1976. The gall-stone of the ox is nearly insoluble in water and alcohol, and appears to consist chiefly of the yellow matter of bile; painters sometimes use it as a yellow pigment.

SECTION V. *Lymph, Mucus, Pus,* &c.

1977. THE liquid which lubricates the different cavities of the body, which is contained in the lymphatics, and which occasionally forms the chief contents of the thoracic duct, has been termed *lymph*. It is colourless, transparent, miscible in all proportions with water, does not affect vegetable blues, is not coagulated by acids or alcohol, but only rendered slightly turbid by the latter. It has the characters of a very weak solution of albumen.

The fluid which collects in cases of dropsy and in vesications, is of a similar nature, but the proportion of albumen is liable to variation, and hence it is differently influenced by tests; when very rapidly thrown out from inflamed surfaces, it sometimes furnishes a coagulum, apparently as abundant as that of the serum of the blood.

1978. The term *mucus* has sometimes been applied to these fluids, when they have undergone a certain degree of inspissation; at other times, it has been used to designate a very alcaline albuminous fluid. Dr. Bostock has pointed out some circumstances in which mucus differs from liquid albumen, and has proposed subacetate of lead as a test for its presence. (NICHOLSON'S *Journal*, Vol. xi.) But that salt is so easily decomposed by many vegetable and animal substances, as to render it of doubtful efficacy for this purpose.

1979. *Saliva* consists, according to Dr. Bostock, (NICHOLSON'S *Journal*, Vol. xiv.) of

Water	80
Coagulated albumen	8
Mucus	11
Saline substances	1
	100

I found that it was copiously coagulable by the action of Voltaic electricity, and was hence induced to consider the mucus as a peculiar albuminous combination, not coagulable by the usual means.—*Phil. Trans.*, 1809.

1980. The *Pancreatic juice* has not been minutely examined, but from the experiments of Dr. Fordyce, it would appear to differ little from saliva.

1981. *Tears* contain a small portion of albumen combined with soda, muriate of soda, and water. There are also small portions of other salts.

1982. *The humours of the Eye.* The *aqueous humour* is composed of water holding a minute quantity of albumen and saline matter in solution; the *crystalline lens* also contains more than half its weight of water, the remainder being an albuminous substance with traces of muriates.

1983. *Synovia* is the fluid which lubricates the surfaces of joints. It contains, according to Mr. Hatchett, (*Phil. Trans.*, 1799.) a small portion of phosphate of lime, and of phosphate of soda and ammonia; the animal principle appeared to be albumen.

1984. *Pus* is a term applied to a variety of secretions from abcesses and ulcerated surfaces. When it indicates a healing sore, it has been called *healthy pus*, and has the following properties. It has the consistency of cream, a yellowish colour, and exhibits, under the microscope, the appearance of globules diffused through a fluid. (Home, *On Ulcers*, 2 Edit., p. 13.) Its specific gravity is about 1.030. It does not affect vegetable colours till it has been some time exposed to air, when it becomes slightly sour; it does not easily mix with water, alcohol, or dilute acids.—See Dr. Pearson's *Experiments on Pus*, Nicholson's *Journal*, xxx.

Section VI. *Urine, Urinary Calculi, &c.*

1985. This secretion presents, perhaps, greater difficulties to the analytical chemist, than any other animal product; it is extremely complex, and subject to constant change in the proportions of its components, and in disease several new substances make their appearance.

The chemical history of the urine is of the utmost importance to the medical practitioner; it teaches the nature of the substances which occasionally predominate, so as to constitute *gravel* and *calculi*; and shows the means of influencing and modifying its composition.

The general characters of the urine are too well known to need description. Its specific gravity is of course liable to much variation even in the healthy state, fluctuating between 1005 and 1040. The average is about 1020.

1986. The substances that are always found in urine are, according to my own experiments, the following:

1. Water.
2. Carbonic acid.
3. Phosphoric acid.
4. Uric acid.
5. Phosphate of lime.
6. Phosphate of ammonia.
7. Phosphate of soda.
8. Phosphate of magnesia.
9. Common salt.
10. Sulphate of soda.
11. Albumen.
12. Urea.

1987. The existence of free acid in recently voided urine is easily demonstrated by its property of reddening vegetable blues, and it performs the important office of retaining some of the difficulty soluble salts in permanent solution; so that whenever this natural acidity is diminished, the urine has a tendency to deposit the earthy phosphates.

1988. The presence of *carbonic acid* may be shown by placing urine under the receiver of the air-pump; during exhaustion it escapes, sometimes copiously, but at other times in minute quantities only.

1989. The free *Phosphoric acid* may be shown by the addition of carbonate of lime, a portion of which is converted into phosphate of lime.

1990. *Uric acid* is one of the peculiar characteristics of the urine; its presence may be shown by evaporating urine to half its bulk, which produces a precipitate consisting of phosphate of lime and uric acid; the former may be dissolved by dilute muriatic acid, which leaves the latter in the form of a reddish powder. This acid has been very ably examined by Dr. Henry, who made it the subject of a thesis published in 1807: Dr. Prout has also given much valuable information in relation to it.

Uric acid, called sometimes lithic acid, as constituting the principal ingredient in certain urinary calculi, may be abundantly obtained by digesting such calculi (2005) in caustic potassa, filtering the solution, and adding excess of muriatic acid, which causes a precipitate of uric acid, which is to be washed with warm water, and dried.

Uric acid thus obtained, is a grey powder, of scarcely any taste, and requiring, according to Dr. Henry, 1720 parts of water at 60°, and 1150 parts at 212° for solution. It reddens *infusion of litmus*, and readily dissolves in caustic potassa, and soda; *it is sparingly soluble* in ammonia, and insoluble in the alcaline carbonates.

According to Dr. Prout, uric acid requires at least 10000 parts of water at 60° for its solution, but urate of ammonia requires only about 480 times its weight at the same temperature, and affords a precipitate of uric acid, on the addition of any other acid; for these, among other reasons, Dr. Prout regards urate of ammonia, and not pure uric acid, as existing in urine.

1991. Uric acid dissolves in nitric acid, and upon evaporation a residuum of a fine red tint is obtained, which is peculiar to this combination, and which Dr. Prout has lately shown to possess distinct acid properties; he has called it *purpuric acid.—Phil. Trans.* 1818.

1992. When uric acid is submitted to destructive distillation, it affords carbonate of ammonia, and a peculiar compound, which sublimes in crystals, and which, according to Dr. Henry, consists of a peculiar acid united to ammonia; a quantity of charcoal remains in the retort. Its ultimate constituents, according to Dr. Prout, are.

1	proportional of	nitrogen	——	14
2	,,	carbon	6 × 2 =	12
1	,,	oxygen	——	8
1	,,	hydrogen	——	1
				35

1993. The *urates* have principally been examined by Dr. Henry, and an account of many of them is given in his *Thesis* above quoted.

1994. *Phosphate of Lime* may be precipitated from urine by the addition of ammonia; its relative quantity is liable to much fluctuation; sometimes it becomes so great as to be deposited as the urine cools, constituting what has been termed *white sand.*

1995. The *Phosphates of Ammonia*, of *Soda*, and of *Magnesia*, and *common Salt*, constitute the principal crystallizable salts contained in the urine; the first of these is probably in great part produced during evaporation, for the saline mass obtained by inspissating urine is no longer acid; the carbonic having escaped, and the phosphoric being saturated by ammonia. The *microcosmic salt*, or *fusible salt of urine*, of the old chemists, is chiefly phosphate of ammonia with a little phosphate of soda, or perhaps a triple *ammonia-phosphate of soda* (598).

1996. The *Ammoniaco-magnesian Phosphate* (692) is a common, and almost constant ingredient in the urine. It forms a part of the white sand voided in certain calculous affections, and is sometimes formed in a film upon the surface of the urine, having been held in solution by carbonic acid, and being deposited as that gas escapes.

1997. The existence of *sulphuric acid*, probably combined with *soda*, and perhaps also with *potassa*, may be detected in urine by the addition of nitrate of baryta, which occasions a precipitate of sulphate of baryta.

As urine blackens silver, it has been said to contain *sulphur;* but this is not the case with recent urine, and when it becomes slightly putrid it evolves a little sulphuretted hydrogen.

1998. The existence of *albuminous matter* in urine is sometimes easily demonstrated; at others, the secretion seems not to contain it. It has been said, by Mr. Cruikshank, that the urine in some dropsical cases contains so much albumen as to be coagulable by heat, (*Phil. Mag*. Vol. ii.) but if that ever be the case, the secretion could hardly be called urine. It seems questionable whether the albumen of urine should not sometimes be regarded as derived from the mucous secretion of the bladder. Dr. Prout, in his *Inquiry into the Nature and Treatment of Gravel*, &c., has described some cases of albuminous urine, and has adverted to its method of cure.

1999. *Urea* is the principle which confers upon urine its chief peculiarities. It may be obtained by slowly evaporating urine to the consistency of syrup; on cooling it concretes into a saline mass, which, by digestion in alcohol, furnishes urea. By carefully distilling off the alcohol, the urea remains in the form of a brown crystallized mass, which, by purification, furnishes colourless prismatic crystals.

Other processes have been given for obtaining urea, which are, I think, objectionable, on account of their complexity; indeed it is doubtful whether, by the action of heat and alcohol, as above described, it is not considerably altered.

Urea is very soluble; water, at 60°, takes up about its own weight, and boiling water appears to dissolve it in any quantity, and without alteration: boiling alcohol takes up its own weight, and on cooling the urea separates in crystals. Sulphuric ether scarcely dissolves an appretiable portion. Nitric acid produces a crystalline precipitate in the aqueous solution of urea, consisting of the two substances according to Dr. Prout, in the following proportions:

Nitric acid - - - - - - - - - - -	47.37
Urea - - - - - - - - - - - - -	52.63
	100.00

A very similar compound may also be produced with oxalic acid.

The fixed alcalis decompose urea, and occasion the evolution of ammonia and some other products. It is to this substance that the copious production of volatile alcali, during the destructive distillation of urine, is referable ; and the ammonia which is found in combination with the acids, in putrid urine, is derived from the same source.

Urea combines with most of the metallic oxides ; with oxide of silver the compound is grey, and it decomposes with detonation, when heated.

According to Dr. Prout's analysis (Henry's *Elements*, Vol. ii. p. 327,) urea consists of

Oxygen - - -	26.66	=	1	proportional	8
Nitrogen - -	46.66	=	1	„	14
Carbon - - -	19.99	=	1	„	6
Hydrogen - -	6.66	=	2	„	2
					30

In some diseased states of the urine there is a morbid excess of urea, which may be detected by putting a little of the urine into a watch-glass, and carefully adding an equal quantity of nitric acid, in such a manner that the acid shall subside to the lower part of the glass ; if spontaneous crystallization take place, it indicates excess of urea.—Prout *on Gravel*, &c., p. 10.

2000. Such are the properties of the principal ingredients in human urine, to which several others have been added by different chemists ; but as their existence is only occasional, and often, I think, doubtful, I have hesitated to give them a place among the regular constituents of healthy urine. I now subjoin Berzelius' statement of the average composition of human urine.—Thomson's *Annals*, Vol. ii. 423.

Water - - - - - - - - - - - - -	933.00
Urea - - - - - - - - - - - - -	30.10
Sulphate of potassa - - - - - - -	3.71
Sulphate of soda - - - - - - - -	3.16
Phosphate of soda - - - - - - -	2.94
Muriate of soda - - - - - - - -	4.45
Phosphate of ammonia - - - - - -	1.65
Muriate of ammonia - - - - - - -	1.50
Free lactic acid - - - - - - - -	17.14
Lactate of ammonia - - - - - - -	
Animal matter soluble in alcohol - - -	
Urea not separable from the preceding -	
Earthy phosphates with a trace of fluate of lime - - - - - - - - - - -	1.00
Uric acid - - - - - - - - - - -	1.00
Mucus of the bladder - - - - - - -	0.32
Silica - - - - - - - - - - - - -	0.03
	1000.00

2001. The urine suffers some very remarkable changes in certain diseases, which have been but superficially inquired into by chemists. In cases of injury of the spine, affecting the nerves that supply the kidneys, the urine is always turbid, and often alcaline; and there is a considerable tendency in these cases to form calculi.

In the disease called *diabetes*, the urine is not only secreted in excess, but often contains a substance of a sweet taste, having the properties of sugar, and its specific gravity is considerably above the healthy standard (Henry *on Diabetic Urine. Medico-Chirurgical Trans.*, Vol. ii. p. 118.) The following Table, constructed by Dr. Henry, shows the quantity of solid extract in a wine pint of urine, of different specific gravities, from 1020 to 1050. In the experiments which furnished the data of this table, the urine was evaporated by a steam heat till it ceased to lose weight, and left an extract which became solid on cooling.—Prout *on Gravel*, p. 62.

Sp. gr. compared with 1000 pts. of water at 60°.	Quantity of Solid extract in a wine pint.	Quantity of Solid extract in a Wine Pint, in			
	grs.	oz.	dr.	scr.	grs.
1020	382.4	0	6	1	2
1021	401.6	0	6	2	1
1022	420.8	0	7	0	0
1023	440.0	0	7	1	0
1024	459.2	0	7	1	19
1025	478·4	0	7	2	18
1026	497·6	1	0	0	17
1027	516·8	1	0	1	16
1028	536·0	1	0	2	16
1029	555.2	1	1	0	15
1030	574.4	1	1	1	14
1031	593.6	1	1	2	13
1032	612.8	1	2	0	12
1033	632.0	1	2	1	12
1034	651.2	1	2	2	11
1035	670.4	1	3	0	10
1036	689·6	1	3	1	9
1037	708·8	1	3	2	8
1038	728·0	1	4	0	8
1039	747·2	1	4	1	7
1040	766·4	1	4	2	6
1041	785·6	1	5	0	5
1042	804·8	1	5	1	4
1043	824.0	1	5	2	3
1044	843.2	1	6	0	3
1045	862.4	1	6	1	2
1046	881.6	1	6	2	1
1047	900.8	1	7	0	0
1048	920.0	1	7	1	0
1049	939.2	1	7	1	19
1050	958.4	1	7	2	18

2002. The urine of graminivorous animals differs considerably from that of the human subject. Carbonates, muriates, and phosphates, are the leading ingredients; it also contains urea, but not uric acid: potassa is usually the predominating alcali. In the *Phil. Trans.* for 1808, I have given an account of the composition of several species of urine, and in that of the camel I detected a small portion of uric acid: but as the animal was diseased, its presence was probably accidental, more especially as it has not been found by other chemists.

In the urine of the snake, and of most birds that feed upon fish and animal matter, uric acid is the leading ingredient. It is also abundant in the excrement of the parrot, and of other birds who feed upon vegetables only.—J. Davy, *Phil. Trans.* 1821.

2003. It frequently happens, from a variety of causes, that certain ingredients of human urine are secreted in excess, and deposited in a solid form, constituting *sand*, or *gravel* and *calculi*.

Sand is either *white* or *red;* the former consists of phosphate of lime, and ammoniaco-magnesian phosphate, either separate or mixed, and the latter is chiefly uric acid. The former deposition is prevented by the use of acids, and the latter by alcalis and the alcaline earths. The modes of exhibiting these remedies, and the effects which they produce, I have described in a paper printed in the *Quarterly Journal of Science and Arts*, Vol. vi.

2004. Urinary calculi are, for the most part, composed of materials that exist at all times in the urine, though there are a few substances that only make their occasional appearance in them. The following are their component ingredients:

1. Uric acid.
2. Urate of ammonia.
3. Phosphate of lime.
4. Ammonio-magnesian phosphate.
5. Oxalate of lime.
6. Carbonate of lime.
7. Cystic oxide.

2005. The calculi composed of uric acid, of which the chemical properties have already been described (1990), are of a brown or fawn-colour; and, when cut through, appear of a more or less distinctly laminated texture. Their surface is generally smooth, or nearly so, being sometimes slightly tuberculated. Before the blow-pipe this calculus blackens, and gives out a peculiar ammoniacal odour, leaving a minute portion of white ash: it is soluble in solution of pure potassa, and heated with a little nitric acid, affords the fine pink compound, above-mentioned (1991).

2006. Phosphate of lime calculus is of a pale brown, or grey colour, smooth, and made up of regular and easily separable laminæ. It is easily soluble in muriatic acid and precipitated by pure ammonia, and does not fuse before the blow-pipe. *Calculi from the prostate gland*, are always composed of phosphate of lime.

2007. The ammonio-magnesian, or triple calculus, is generally white, or pale grey, and the surface often presents minute crystals; its texture is generally compact, and often somewhat hard and translucent; heated violently by the blow-pipe, it exhales ammonia, and leaves phosphate of magnesia. It is more easily soluble than the preceding, and oxalate of ammonia forms no precipitate in its muriatic solution.

2008. It frequently happens that calculi consist of a mixture of the two last-mentioned substances, in which case they melt before the blow-pipe, and are hence termed *fusible calculi*. They are white or nearly so, and softer than the separate substances, often resembling chalk in appearance. They are easily soluble in muriatic acid, and if oxalate of ammonia be added to their solution, the lime is precipitated in the state of oxalate.

2009. Oxalate of lime forms calculi, the exterior colour of which is generally dark brown, or reddish; they are commonly rough, or tuberculated upon the surface, and have hence been called *mulberry calculi*. Before the blow-pipe they blacken and swell, leaving a white infusible residue, which is easily recognised as quicklime (1736). Small oxalate of lime calculi are, however, sometimes perfectly smooth upon the surface, and much resemble a hempseed in appearance.

2010. Urate of ammonia I admit among urinary calculi, upon the authority of Dr. Prout, my own experiments having formerly induced me to doubt its existence (*Phil. Trans.* 1808). Its surface is sometimes smooth, sometimes tuberculated; it is made up of concentric layers, and its fracture is fine earthy, resembling that of compact limestone; it is generally of a small size, and rather uncommon, though it often occurs mixed with uric acid. It usually decrepitates before the blow-pipe, is more soluble than the uric calculus, evolves ammonia when heated with solution of potassa, and is readily soluble in the alcaline carbonates, which pure uric acid is not.

2011. Dr. Prout and Mr. Smith (*Med. et Chir. Trans.* xi. 14.) have described calculi composed almost entirely of carbonate of lime, but this species is exceedingly rare, and among several hundred calculi which I have examined, I never met with it from the human bladder.

2012. Cystic oxide is a peculiar animal substance; the calculi composed of it, which are rare, are in appearance most like those of the ammonio-magnesian phosphate. They are soft, and when burned by the blow-pipe, exhale a peculiar fœtid odour. They are soluble in nitric, sulphuric, muriatic, phosphoric, and oxalic acids, and also in alcaline solutions.

2013. The substances which have been described, with the exception of cystic oxide, are sometimes intimately blended in calculi; sometimes they form alternating layers; and in a few cases four distinct layers have been observed, the nucleus being uric, upon which the oxalate, and phosphate of lime, and the triple phosphate, are distinctly and separately arranged.

2014. Dr. Marcet has described a calculus composed of a peculiar animal matter, which he calls *Xanthic Oxide*, from its property of giving a yellow colour when acted on by nitric acid: he has also announced the existence of calculus composed of *fibrine*.—*Essay on Calculous Disorders*, *2d edit.* p. 103.

2015. These are the principal chemical facts belonging to the history of urinary calculi. In Dr. Wollaston's valuable papers upon this subject (*Phil. Trans.* 1797 and 1810,) much additional information will be found. In the same work (1806, 1808, and 1810,) I have given some account of their peculiarities, depending upon their situation, and have also discussed the operation of solvents, a subject which I have taken up more in detail in the *Quarterly Journal of Science and the Arts*, Vol. viii. Dr. Marcet and Dr. Prout have also published excellent dissertations on *Calculous Disorders*, containing all that is most important upon the subject.

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SECTION VII. *Cutis, or Skin; Membrane, &c.*

2016. THE skin of animals consists of an exterior albuminous covering, or *cuticle*, under which is a thin stratum of a peculiar substance, called by anatomists *rete mucosum*, and which lies immediately upon the *cutis*, or true skin, of which the principal component is *gelatine*.

2017. The following are the chemical properties of pure gelatine. It is colourless, semi-transparent, and nearly tasteless. It is softened by long-continued immersion in cold water: in hot water it readily dissolves, and forms a solution of a slightly milky appearance, which, if sufficiently concentrated, concretes on cooling into the tremulous mass usually called *jelly*, and which is easily soluble in cold water; when dried in a gentle heat it acquires its original appearance, and is as soluble as before. When dry, gelatine undergoes no change, but its solution soon becomes mouldy and putrescent. Submitted to the action of heat it affords the usual products of animal substances.—HATCHETT. *Philos. Transact.* Vol. xc.

It is readily soluble in diluted acids and alcaline solutions, and forms no soap with the latter. Its aqueous solution is not affected by solution of corrosive sublimate, and few of the metallic salts occasion any precipitate in it. Chlorine passed through its solution, occasions a white elastic matter to separate, which is not soluble in water, and which in some properties resembles albumen. It is insoluble in alcohol and ether. Solution of tannin occasions a white precipitate in solution of gelatine; and hence, vegetable astringents such as galls or catechu, are generally employed as tests for its presence. But as tannin precipitates albumen, it cannot be relied on as an unequivocal test, unless we previously ascertain the non-existence of albumen by corrosive sublimate.—BOSTOCK. NICHOLSON'S *Journal*, xiv. and xxi.

Mr. E. Davy recommends sulphate of platinum as a very delicate test of gelatine, with which it forms a brown insoluble compound, in solutions too weak to be affected by vegetable astringents.—*Phil. Trans.* 1820, p. 119.

2018. The action of sulphuric acid upon gelatine has been investigated by M. Braconnot. Twelve parts of powdered glue and 24 of sulphuric acid, were left together for 24 hours; about 60 parts of water were then added, and the whole boiled for 5 hours, adding water at intervals; the solution was then saturated with chalk, filtered, and suffered to evaporate spontaneously. In a month crystals were deposited, which, being purified by solution and a second crystallization, much resembled sugar of milk, though they differ from that substance in affording a peculiar acid, called by M. Braconnot *Nitro-saccharine acid*, when acted upon by nitric acid.—*Ann. de Chimie et Phys.*, xiii.

2019. The different kinds of gelatine differ considerably in viscidity.

Mr Hatchett has remarked that the gelatine obtained from skins possesses a degree of viscidity inversely as their softness or flexibility; the most adhesive kinds of gelatine, too, are less easily soluble in water than those which are less tenacious. The principal varieties of gelatine in common use are,

a. *Glue*, which is prepared from the clippings of hides, hoofs, *&c.*, obtained at the tan-yard; these are first washed in lime-water, and afterwards boiled and skimmed; the whole is then strained through baskets, and gently evaporated to a due consistency; afterwards it is cooled in wooden moulds, cut into slices, and dried upon coarse net-work. Good glue is of a semi-transparent and deep brown colour, and free from clouds and spots. When used it should be broken into pieces, and steeped for about 24 hours in cold water, by which it softens and swells; the soaked pieces may then be melted over a gentle fire, or in a water-bath, and in that state applied to the wood by a stiff brush. Glue will not harden in a freezing temperature, the stiffening depending on the evaporation of its superfluous water.

b. *Size* is less adhesive than glue, and is obtained from parchment shavings, fish-skin, and several animal membranes. It is employed by bookbinders, paper-hangers, and painters in distemper, and is sometimes mixed with flour, gum, *&c.*

c. *Isinglass* is prepared from certain parts of the entrails of several fish; the best is derived from the sturgeon, and is almost exclusively prepared in Russia. It should be free from taste and smell, and entirely soluble in warm water, which is seldom the case, in consequence of the presence of some albuminous parts. When the jelly of isinglass is concentrated by evaporation and carefully dried, it forms a very choice kind of glue.—AIKIN'S *Dictionary*, Art. GELATINE.

2020. *Leather* is a compound of gelatine and vegetable astringent matter, formed by steeping the skins of animals in the infusions of certain barks. The skins are previously prepared by soaking in lime-water, which renders the cuticle and hair easily separable, and are afterwards softened by allowing them to enter into a degree of putrefaction. In this state they are submitted to the action of infusion of oak-bark, or other astringent vegetable matter (1602), the strength of which is gradually increased until a complete combination has taken place, which is known by the leather being of an uniform brown colour throughout; whereas, in imperfectly tanned leather a white streak is perceptible in the centre.

Tawed leather is made by impregnating the skin duly prepared, with a solution of alum and common salt; it is afterwards trodden in a mixture of yolk of eggs and water.

Curried leather is made by besmearing the skin, or leather, while yet moist, with common oil, which, as the humidity evaporates, penetrates into the pores of the skin, giving it a peculiar suppleness, and making it, to a considerable extent, water-proof. As familiar examples of these processes, the thick sole-leather for shoes and boots is *tanned*; the upper-leather is *tanned* and *curried*; the white leather for gloves is *tawed*; and fine Turkey-leather is *tawed*, and afterwards slightly *tanned*.—AIKIN'S *Dictionary*, Art. LEATHER.

2021. The different *membranes* of the body, and the *tendons*, are chiefly composed of gelatine, for by long digestion in warm water they gradually soften, and become ultimately almost perfectly soluble.

SECTION VIII. *Muscle, Ligaments, Horn, Hair, &c.*

2022. WHEN the *muscular parts* of animals are washed repeatedly in cold water, the fibrous matter which remains consists chiefly of albumen, and is in its chemical properties analogous to the clot of blood (1957). Muscles also yield a portion of gelatine; and the flesh of beef, and some other parts of animals, afford a peculiar substance of an aromatic flavour, called by Thenard, *osmazome.*

2023. 30 parts of beef fibre, acted on by as much sulphuric acid, yielded M. Braconnot, a portion of fat, and on diluting the acid mixture, and saturating with chalk, filtering, and evaporating, a substance, *tasting like* osmazome was obtained, which was often boiled in different portions of alcohol: the alcoholic solutions, on cooling, deposited a peculiar white pulverulent matter, which Braconnot calls *leucine*, and which acted upon by nitric acid affords a crystallizable *nitroleucic acid.*—*Annales de Chimie et Phys.*, xiii. p. 118.

2024. *Ligaments*, *horn*, *nail*, and *feathers*, consist principally of albumen.

2025. *Hair* consists principally of a substance, having the properties of coagulated albumen. It also contains gelatine, and the soft kinds of hair yield it more readily than those which are harsh, strong, and elastic.—HATCHETT. *Phil. Trans.* 1800.

Vauquelin discovered in hair two kinds of oil; the one white, and existing in all hair; the other coloured, yellow from red hair, and dark coloured when obtained from dark hair. Black hair also contains iron and sulphur. He supposes that where hair has become suddenly gray, the effect is produced by the evolution of acid matter, which has destroyed the colour of the oil.

2026. *Feathers*, *quills*, and *wool*, are also possessed of the properties of albumen, and appear to contain no gelatine.

SECTION IX. *Fat, Spermaceti*, &c.

2027. THE fat of animals, when freed by fusion or pressure from cellular membrane, is of various degrees of consistency, as seen in *tallow*, *lard*, and *oil*. When pure, it has little taste or smell, but it acquires both by keeping, and becomes rancid and slightly sour. The softer varieties fuse at about 90°, and the harder at 120°. Decomposed at a red heat, they afford abundance of olefiant gas, and a small portion of charcoal; products analogous to those of vegetable oil. (741.) When burned, they produce water and carbonic acid, containing the same ultimate elements, in the same proportions as vegetable oils. (1634.)

They also produce soaps by combination with alcalis.

Nitric acid, heated in small quantity with any of the fatty substances, renders them harder, and considerably increases their solubility in alcohol. Among the vegetable oils this change is most remarkably produced upon cocoa-nut, and castor-oils, the latter becoming converted into a solid matter, which, when cleansed of adhering acid by washing, resembles soft wax.

2028. The experiments of Braconnot and Chevreul, already quoted, (1628) have shown that the different kinds of oil and fat contain two substances, to which they have given the names *stearine* and *elaine*, the former solid, the latter liquid at common temperatures. The following table shows their relative proportions in different fats and oils :

	Elaine.	Stearine.
Butter, made in summer	60	40
Ditto, winter	37	63
Hogs'-lard	62	38
Beef-marrow	24	76
Mutton ditto	74	26
Goose-fat	68	32
Ducks'-fat	72	28
Turkey's-fat	74	26
Olive-oil	72	28
Almond-oil	76	24

These principles may be obtained by boiling hogs'-lard in alcohol ; the fluid, on cooling, deposits a crystalline matter, which is to be purified by a second solution and crystallization ; it is then pure *stearine*, white, brittle, tasteless, and inodorous ; it fuses at a little below 120°, and forms soap with alcalis.

When the alcohol which has deposited the whole of the stearine is distilled, an oily liquid remains, which is *elaine*. It is fluid at 58° ; it generally is of a yellow colour, and is convertible into soap.

2029. When soap composed of hogs'-lard and potassa, is put into water, a portion only is dissolved the remainder consists of white scales, composed of the alcali united to a peculiar acid, called by Chevreul, from its pearly appearance, *margaritic acid*, and separable from the above combination by muriatic acid.

It is insoluble in water, tasteless, fusible at 134°, and crystallizes on cooling in brilliant white needles. It is soluble in alcohol. It unites with potassa in two proportions, the one compound containing 100 acid + 8.80 potassa ; the other, 100 acid + 17.77 potassa. These compounds have been termed *margarates of potassa*.

2030. The portion of the hogs'-lard soap soluble in water, consists of another peculiar substance united to potassa, which Chevreul has called *oleic acid*. It may be obtained from its solution by tartaric acid, which causes it to separate in the form of an oily matter, that is to be again united to potassa, and separated as before. This substance solidifies at about 40°, and it forms compounds, called *oleates*. It appears probable that, by the action of alcalis, the stearine is converted into what Chevreul has termed margaric acid, and the elaine into oleic acid. *Annales de Chimie*, xciv.

2031. By mixing 1 volume of carbonic acid with 10 of carburetted hydrogen, and 30 of hydrogen, and passing the mixture through a red-hot porcelain tube. Berard is said to have produced a substance in small white crystals, having many of the properties of fat.—THOMSON'S *Annals*. xii.

2032. *Spermaceti* or *Cetine* is a peculiar matter, which concretes from the oil of the *spermaceti whale*. It fuses at 112°, and at higher temperatures is volatile, but if repeatedly distilled it loses its solid form, and becomes a liquid oil. It is soluble in boiling alcohol, and abundantly so in ether. It forms a soap with potassa, which yields, on decomposition, a substance called by Chevreul, *cetic acid*.—*Annales de Chimie*, xcv.

2033. In the *yolk* of *eggs* there is a considerable quantity of oily matter, which may be obtained by pressure after boiling; it is yellow and tasteless.

2034. *Ambergris*, which is a concretion from the intestines of the spermaceti whale, also contains a considerable portion of fatty matter, amounting in some specimens to 60 *per cent*. It is only found in the unhealthy animal.—HOME's *Lectures on Comparative Anatomy*, Vol. i., p. 470.

2035. The brain of animals, when boiled in alcohol, furnishes a peculiar fatty matter, which the solution deposits as it cools, in brilliant scales. It requires a higher temperature than that of boiling water for its fusion, and appears in many respects analogous to cholesterine. (1974.) The same substance is often seen in the alcohol employed to preserve anatomical preparations of the brain and nerves.

SECTION X. *Cerebral Substance.*

2036. ACCORDING to Vauquelin, the *cerebral substance* consists of

Water	80.00
White fatty matter	4.53
Red fatty matter	0.70
Albumen	7.00
Osmazome	1.12
Phosphorus	1.50
Acids, salts, and sulphur	5.15
	100

The *pulp of nerves* seems to be of a similar nature.—THOMSON's *System*, Vol iv., p. 482.

SECTION XI. *Shell and Bone.*

2037. WE are indebted to Mr. Hatchett for two excellent dissertations on the chemical properties of these parts of animals, published in the *Philosophical Transactions* for 1799 and 1800.

He has divided *shells* into two classes; the texture of the first is compact, brittle, and resembling porcelain; their surface is smooth, and they are often beautifully variegated. When exposed to a red heat they crackle, and lose the colour of their enamelled surface, emitting scarcely any smoke or smell. They dissolve in dilute muriatic acid with copious effervescence, and form a transparent solution, in which neither pure ammonia nor acetate of lead produce any precipitate, but carbonate of ammonia throws down carbonate of lime. Hence these, which are called *porcellaneous shells*, may be considered as composed of carbonate of lime, united to a very small portion of gelatine: most of the univalve shells, such as whelks, limpets, cowries, and many of the beautiful convoluted shells of tropical countries, belong to this class.

2038. The second class, or *mother-of-pearl shells*, are tougher, glossy, and iridescent; they are mostly bivalves, and all the oyster and muscle species belong to it. When heated, they exhale smoke and the smell of burned horn; immersed in muriatic acid, they only partially dissolve, and leave a series of cartiliginous layers, and an outer epidermis. Each membrane appears to have a corresponding stratum of carbonate of lime, the solution indicating no trace of any phosphate. The animal part is in some cases, as in mother-of-pearl, tough and indurated, and when dried becomes exactly like horn; in other instances, as in the bone of the cuttle fish, it appears in the form of delicate and tender membrane.

In both classes of shells, therefore, the hardening principle is carbonate of lime; in porcellaneous shells there is very little animal matter, which is gelatine; and in mother-of-pearl shells, it is albumen, and in larger quantities.

2039. *Pearls* are exactly similar in composition to what is termed *mother-of-pearl*, in which Mr. Hatchett found

Carbonate of lime	66
Albumen	24
	100

2040. In the *scales of fish*, and in the *crusts* of lobsters, crabs, prawns, and cray-fish, Mr. Hatchett found the animal portion to consist of cartilage; the hardening part was a mixture of carbonate and phosphate of lime. From *lobster-shell* Merat-Gulliot obtained

Carbonate of lime	60
Phosphate of lime	14
Cartilage	26
	100

Vauquelin obtained from 100 parts of *hen's egg-shell*

Carbonate of lime	89.6
Phosphate of lime	5.7
Animal matter	4.7
	100

2041. *Zoophytes*, according to Mr. Hatchett's researches, may be divided into four classes; the first resemble porcellaneous shells, and consist entirely of carbonate of lime, with a very minute quantity of perfect division of the stomach into two cavities, by the contraction of the bands of muscular fibres about its centre.[*] He has also shown that these liquids, very soon reach the kidneys, and pass off by urine; and was led to believe that the spleen was the channel of communication; an opinion, however, which his subsequent researches tended to disprove.—*Lectures on Comparative Anatomy*, p. 221.

Chyle. The chyme passes from the stomach into the small intestines, where it soon changes considerably in appearance; it becomes blended with bile, and is separated into two portions, one of which is white as milk, and is termed *chyle*; the other passes on to the large intestines, and is ultimately voided as excrementitious. The chyle is absorbed by the *lacteals*, which terminate in the common trunk, called the *thoracic duct*; it is there mixed with variable proportions of lymph, and poured into the venous system.

The *excrements of animals* have been examined by Berzelius, (GEHLEN's *Journal*, vi.); by Vauquelin, (*Annales de Chimie*, xxix.); and by Thaer and Einhoff. An abstract of these experiments has been published by Dr. Thomson, in the 4th volume of his *System of Chemistry*.

2047. *Chyle* has been examined by several chemists, and their results are not widely different. During some physiological researches in which I assisted Mr. Brodie, I had an opportunity of collecting it in considerable quantities in several carnivorous and graminivorous animals, and presented an account of my experiments upon it to the Royal Society.—*Phil. Trans.*, 1812, p. 91.

Characters. Chyle is an opaque white fluid, having a sweetish saline taste; its specific gravity is inferior to that of the blood. It exhibits slight traces of alcaline matter when tested by infusion of violets; soon after removal from the thoracic duct, it gelatinizes spontaneously, and afterwards gradually separates into a firm yellowish white coagulum, and a transparent colourless serum; so that, like the blood, it enjoys the property of spontaneous coagulation.

The *coagulum of chyle* possesses properties closely resembling those of the caseous portion of milk, and may hence be considered as a variety of albumen; the *serum of the chyle*, when heated, deposits a few flakes of albumen, and by evaporation to dryness affords a small proportion of a substance analogous to sugar of milk. Small portions of phosphate of lime, carbonate of soda, and common salt, may also be detected in the chyle. In these experiments I found no distinctive difference in the chyle of graminivorous and carnivorous animals; I examined it from the horse, the ass, the dog, and the cat; Dr. Marcet thinks that the former is less abundant in albumen than the latter[*].—THOMSON's *Annals*, Vol. vii.

Bile. 2048. There can be little doubt that the bile performs an important part in the change which the chyme suffers in the small intestines; it has been conjectured that its aqueous, and perhaps its alcaline, parts, are employed as components of chyle, while the albumino-resinous matter combines with the excrementitious portion, and tends to stimulate the intestinal canal towards promoting its propulsion. Whether the bile is absolutely necessary to the formation of chyle, is a question that has not been satisfactorily answered; but its importance is demonstrated by the emaciation that attends its deficiency, and by the disordered state of bowels that accompanies its imperfect secretion. Sir Everard Home, in his *Lecture on the Functions of the Lower Intestines*, (*Lectures*, p. 468.) has offered some curious facts connected with this subject, to which I refer the physiological reader. He is of opinion that, in the large intestines, a portion of the food unfit for chylification is, by a process not widely different from that above described, (1951) converted into fat, which is afterwards absorbed and conveyed to different parts of the body.

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[*] It is a curious question, whence the nitrogen, which constitutes an abundant ultimate principle of the chyle of herbivorous animals, is derived; we find it in very small proportion only in their ordinary food, and yet I could discern no difference in the composition of the albuminous portion of their chyle, and that of animals fed exclusively on meat.

2049. In chyle we cannot fail to observe a close approximation to blood: it is deficient only in colouring matter, and the albumen which it contains differs a little from that existing in the blood itself; it appears, therefore, that the albumen is perfected, and the colouring matter formed, in the process of circulation; the saccharine principle of the chyle is also no longer perceptible.

2050. The difference between arterial and venous blood, has been adverted to in a previous section; the former is of a florid red colour, and circulates in the arterial system; it is contained in the left ventricle of the heart, and thence carried by the *aorta*, and its ramifications, to every part of the body, tending to re-production and secretion: it afterwards enters the veins which arise from the extremities of the arteries, and form accompanying branches and trunks ultimately uniting in the *venæ cavæ*, which pour their contents into the right auricle of the heart; the venous blood is thence propelled into the right ventricle, from which the pulmonary artery arises, transmitting it through the lungs, whence it is returned by the pulmonary vein into the left auricle, which transmits it to the left ventricle, from which issues the aorta as aforesaid. So that the right cavities of the heart receive venous blood, and transmit it through the lungs, whence it returns to the left side of the heart, in the arterial state. In the lungs the blood is infinitely subdivided, and spread over a very large surface in vessels so delicate as to admit of the operation of the atmospheric air contained in their cells; it enters the pulmonary structure in the *venous* state by the *pulmonary artery*, and returns in the *arterial* or *aërated* state, by the *pulmonary vein*. It now remains to examine the changes which the blood undergoes during pulmonary circulation.

2051. *Respiration* is the process of receiving a quantity of air into the lungs, whence, after having been retained a short time, it is again expelled in the action of exspiration; and, if now examined, a portion of its oxygen is found converted into carbonic acid, and it is more or less loaded with aqueous vapour.

Number of respirations. Obvious circumstances render it very difficult to ascertain the quantity of air taken into the lungs at each natural inspiration, as well as the number of respirations made in a given time; the former is perhaps about 15 or 16 cubic inches, and the latter about 20 in a minute.

Changes of the air respired. It has been by some supposed that the air suffers an absolute diminution of bulk, but the experiments that have been adduced to prove this, can, I think, scarcely be regarded as satisfactory; it seems, on the contrary, most probable that the volume of air expired is exactly equal to that inspired, and consequently the only chemical change that is evident is the saturation of a portion of its oxygen with carbon. The quantity of carbonic acid emitted at each exspiration, varies at different periods of the day, and probably also in different individuals; it appears at its maximum during digestion, and at its minimum in the morning, when the stomach is empty, and when no chyle is flowing into the blood. Dr. Prout has shown that fermented liquors and vegetable diet diminish the proportion of carbonic acid, and that the same thing happens when the system is affected by mercury. (THOMSON's *System*, iv. 621.)

Quantity of carbonic acid. The air expired may be regarded, I think, as containing, on an average, 3.5 *per cent.* of carbonic acid, though Messrs. Allen and Pepys, in their valuable *Essay on Respiration*, (*Phil. Trans.*, 1808.) have estimated it at about twice that quantity; it amounted, in their experiments, to 27.5 cubic inches per minute, a quantity probably above the truth, when we reflect upon the comparative proportion of carbon existing in our food, and the other means of escape which it has from the body.

The aqueous vapour contained in the expired air is secreted by the exhalents distributed over the surface of the air-vessels of the lungs; attempts have been made to estimate its quantity, but without success; it is probably liable to variation, and can scarcely be considered as a product of respiration.

It has been above stated that the whole of the venous blood is propelled through the vessels of the lungs, where it is subjected to the action of the air; the chyle is of course carried along with it, and when it returns by the pulmonary vein to the left side of the heart, it has undergone a considerable change in appearance, having lost its dingy colour, and acquired a fine florid red; the chyle also has become perfect blood. The change of colour is evidently owing to the action of the air, which takes place through the thin coats of the circulating vessels, and the end thus attained is the removal of the carbon from the venous blood, by which the colouring matter was obscured: the carbon to be thus readily soluble in oxygen must be in some peculiar state; a portion of it is also removed by the absorbents, and transferred to the glands situate at the root of the lungs between the subdivisions of the bronchiæ, which often contain a large portion of black matter. This has sometimes been referred to soot inhaled with the air, but many circumstances render it more probable that it is a carbonaceous deposit from the blood. The only chemical difference, then, which can be detected between arterial and venous blood, is the existence of a certain excess of carbon in the latter, which it gives off to oxygen, forming carbonic acid; the blood is thus fitted for the renovation of parts, for the formation of secretions, and for the sustenance of life by its action on the cerebral system; for although the heart does not directly refuse to circulate venous blood, paralysis and torpor ensue when blood, not aërated, passes into the vessels of the brain.

Perspiration. 2052. It has already been shown that the blood suffers very important changes in the kidneys and liver; the function of *perspiration* also must be considered as connected with an alteration of the circulating fluid, for moisture, carbonic acid, and minute quantities of phosphoric acid, and saline matter, among which is common salt, are evacuated by the cutaneous vessels. This quantity of humidity is sometimes very considerable, especially during violent exercise in warm weather, and it contributes materially to diminish the temperature of the body; a portion of water, however, is at all times passing off by the skin, as may be seen by putting the hand into a dry and cold glass, which soon becomes dimmed by the condensation of vapour.

Unequal quantities of oxygen necessary to different animals.

2053. Different animals require very different quantities of oxygen for the purposes of respiration. Man, and warm-blooded animals, consume the largest quantity; the amphibious tribes not only require less, but can breathe in an atmosphere which will not support the life of the former; and many insects take such small quantity, as sometimes to have been supposed capable of living without air, which is not the case. In the production of carbonic acid all animals agree, and consequently the nature of the deterioration suffered by the air is similar throughout the animal creation.

Fishes breathe the air which is dissolved in water; they therefore soon deprive it of its oxygen, the place of which is supplied by carbonic acid; this is in many instances decomposed by aquatic vegetables, which restore oxygen, and absorb the carbon (1535); hence the advantage of cultivating growing vegetables in artificial fish-ponds. it has been ascertained by Biot, and verified by others, that the air-bladders of fish that live in very deep water are filled with a mixture of oxygen and nitrogen, in which the former greatly preponderates; but in fish that are taken near the surface, the nitrogen is most abundant. In the *trygla lyra*, always caught in very deep water, the air-bladder contained 87 *per cent.* of oxygen: in the carp and roach, according to Fourcroy and Priestley, the air-bladder contains little else than nitrogen.—BIOT, *Mémoires d' Arcueil*, i. & ii.

Animal heat.

2054. The production of *animal heat* is perhaps the most recondite of all the functions; the power appears to belong to all animals, though to some in a very inferior degree. The higher orders of animals always maintain a temperature of about 100°; it varies a little in different parts of the body, the extremities and surface being a degree or two colder than the interior vital organs. This temperature is probably very little affected by external circumstances, a hot or cold atmosphere producing no corresponding change in the heat of the circulating blood.

When the chemical changes that take place during respiration had been inquired into, and when it was found that the capacity of carbonic acid for heat was less than that of oxygen, it was supposed that the conversion of oxygen into carbonic acid was the cause of the rise of temperature: and as the heat of the lungs does not exceed that of other parts, it was asserted that the air was absorbed by the blood, and that the production of carbonic acid, and consequent evolution of heat took place gradually during the circulation. To these opinions many strong objections have from time to time been urged by different physiologists, but their complete subversion followed the researches of Mr. Brodie, (*Phil. Trans.*, 1812.) who found that the heart was capable of retaining its functions for some hours, and of carrying on circulation in a decapitated animal, and consequently independent of the influence of the brain, when respiration was artificially carried on. Under these circumstances it was observed, that although the change of blood from the venous to the arterial state was perfect, no heat was generated, and that the animal cooled regularly and gradually down to the atmospheric standard. In more than one instance I examined, at his request, the expired air, and found that it contained as much carbonic acid as was produced by the healthy animal; so that here, circulation went on, there was the change of oxygen into carbonic acid, and the alteration of colour in the blood, and yet no heat whatever appeared to be generated.

In these cases a period was also put to the secretory functions; and it has been observed by several other physiologists, that if the nerves that supply any of the glands are injured or divided, there is a corresponding change or suspension of their secretion. Electricity has sometimes been supposed to have some connexion with the nervous influence, and the fact of some of the secretions being alcaline, while others are acid (corresponding to negative and positive influence), has been adduced in favour of the supposition*, but experiment has gone little way to sanction such a notion, and although it has been proved that the nervous influence contributes to the generation of heat in animals, that it presides over the phænomena of secretion, as well as of voluntary motion, the actual cause of this influence, or energy, remains among those mysteries of nature which, doubtless, for the wisest purposes, are hidden to the human understanding.

CHAPTER X.

GEOLOGY.

2055. Having detailed the properties of the elementary bodies, and of their natural and artificial combinations, and having described the products of the vegetable and animal creation, it remains in this, the concluding chapter, to notice the general arrangements of the mineral world, to describe the mutual relations of the substances constituting the surface of our globe, and to examine their characters and composition: these investigations form the object of geological science.

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* In the *Philosophical Transactions* for 1809, p. 385, Sir Everard Home has given an account of these views, in a paper entitled *Hints on the Subject of Animal Secretions*.

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SECTION I. *General Remarks on the Objects of Geological Science.—Sketch of the Theories of Burnet, Woodward, Leibnitz, Whiston, Whitehurst, and Buffon.—Wernerian and Huttonian Theories.*

2056. GEOLOGY embraces so many topics of discussion, its range is so extensive, and the meanings given to the term are so various and opposite, as to throw no inconsiderable difficulties in his way who would enumerate and expound them. Persons have been called geologists, who, gifted with prolific imaginations, have indulged in fanciful speculation concerning a former order of things, and have reared hypotheses respecting the origin of our planet, upon foundations so flimsy and unsubstantial, as to deserve no other appellation than flighty excursions of a poetic mind. Others, by careful, diligent, and extended observations of the present state of the earth's surface, have endeavoured, in the path of induction, to trace the nature of the agents which have once been active, to ascertain how far they are now operating, and to anticipate the results of their continuance. If they frame theories, they do so upon the results of actual research; if they indulge in speculation, they assign to it its proper place. These are really geologists, and their aim is, not to imagine or suppose, but to *discover* the nature of all changes of the earth's surface and interior, and thence to arrive at the laws that regulate them.

Geology, as a branch of inductive science, is of very modern date; for though the attention of men has long been turned to a theory of the earth, the formation of such a theory is incompatible with any but an advanced state of physical knowledge. There appear, indeed, few studies of more difficulty; none in which the subject is more complex; appearances so diversified and scattered; and where the causes that have operated are so remote from the sphere of ordinary observation.

2057. The first writer upon this subject, whose name merits notice, is Thomas Burnet*, who may justly be said to have adorned the latter half of the seventeenth century. And though it be true that his pen has rather recorded the sallies of a vivid imagination, than the inferences of sober argument, he will still be read with some profit, though certainly with more pleasure, even in these times. The objection to Burnet and his contemporaries, and immediate successors, is, that they fancifully go back to the chaotic state of the earth, and after enlarging, embellishing, and obscuring the Mosaic history, they pretend to have illustrated and proved it. Accordingly, Burnet, in his *Sacred*

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* *The Sacred Theory of the Earth, containing an account of the Original of the Earth, and of all the General Changes which it hath already undergone, or is to undergo, till the Consummation of all Things.* (8vo., London, 1726.) Published originally in Latin in 1681 and 1689.

Theory of the Earth, begins with the separation of elements from a fluid mass. The heaviest particles sank, and formed a nucleus, and water and air took their respective stations: upon the water, however, the air afterwards deposited a rich unctuous crust, which begat vegetation, and a beautiful verdure clothed the whole. There were no mountains, no seas, no protuberances, or inequalities; and the equator being coincident with the plane of the ecliptic, all the charms of spring were perpetual. This state of things, however, did not thus continue for many centuries; for the sun caused large cracks and fissures in the exterior, which, by gradual increase, extended to the great aqueous abyss; the waters rose higher and higher, the surface was utterly broken up and destroyed, and an universal deluge took place: at length dry land began again to appear, owing to a gradual subsidence of the waters, which retired into caverns and crevices originally existing in the nucleus, or formed by the disruption of the crust; upon the increasing dry land, vegetation began again to exist, and our present islands and continents were formed, while the sea still occupies in part its original bed.

I do not recite the minutiæ of Burnet's romance, nor shall I meddle with the adjustments of these and the like speculations to the records of Holy Writ. If, in the laborious path of experimental investigation, we are occasionally rewarded with the discovery of some new adaptations of causes and effects, which had before escaped notice, but which demonstrate how all things on earth are made to work together for good, the discovery strengthens our faith, and calls forth the best feelings of which the human heart is susceptible; but we must not presume to submit the aptitude of nature's arrangements to the feeble powers of human decision, to doubt her perfection, because our imbecile capacities cannot attain its comprehension, or to found our proofs of the existence, or even of the attributes, of the Deity, upon the limited, imperfect, or ideal conception of the excellence of nature's works, of which the human understanding is capable.

Although Burnet's Theory, as he calls it, was a mere hypothetical product of the imagination, unsupported by a single fact, or by the slightest observed phænomenon, it excited much admiration and some discussion, and was criticised with much acrimony and some ability*; more especially by Keill, of Oxford†. His style is in general terse and elegant, though it occasionally degenerates into the predominant pomposity of the period at which he wrote. He was the translator of his own work from Latin into English. Two brief samples from the latter will be sufficient for elucidation. After observing that the obscurity and remoteness of his subject has by some been used as an argument against undertaking it, "This," says he, "does but add to the pleasure of the contest where there are hopes of victory, and success more than recompenses all the pains. No joy is more grateful to man than the discovery of truth, especially where it is hard to come by. Every man has a delight suited to his genius, and as there is pleasure in the right exercise of any faculty, so especially in that of right reasoning, which is still the greater by how much the consequences are more clear, and the chains of them more long. There is no chase so pleasant, methinks, as to drive a thought from one end of the world to the other, and never to lose sight of it till it falls into eternity, where all things are lost, as to our knowledge."

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* By Dr. Herbert Crofte, in 1685: by Dr. Beaumont, in 1693, and by Erasmus Warren.

† *An Examination of Dr. Burnet's Theory*, &c., by J. Keill. A. M., of Baliol Coll., Oxon. Second Edition, 1734, 8vo. "He (Burnet) begins his discourse with a saying of an old heathen, that philosophy is the greatest gift that ever God bestowed on man; but it is plain to any who will be at the pains to read his book, that God has thought fit to bestow but very little of that great gift upon him, and, that the world may not say this is ill-nature, I will give them a taste of his phylosophy," &c.

This is the general style of the *Examination*.

The following passage from Burnet's work has been highly eulogized by Steele*, and certainly it merits praise; it is a funeral oration over the globe: "Let us now," says he, "reflect on the transient glory of the earth; how, by the force of one element breaking loose on the rest, all the beauties of nature, each work of art, and every labour of man are reduced to nothing; all that once seemed admirable, is now obliterated: all that was great and magnificent, has vanished; and another form and face of things, plain, simple and uniform overspreads the earth. Where are now the empires of the world? where the imperial cities, the pillars, trophies, and monuments of glory? what remains, what impressions or distinctions do you now behold? what is become of Rome, the great city; of eternal Rome, the empress of the world, whose foundations were so deep, whose palaces were so sumptuous?—her hour is come; she is wiped from the face of the earth, and buried in everlasting oblivion. But not the cities only, and the works of men's hands, but the hills and mountains, and rocks of the earth, are melted as wax before the sun, and their place is no where found; all have vanished and dropped away, like the snow that once rested upon their summits†."

It is impossible to read this quotation, without being reminded of one of the most beautiful passages in the *Art of Preserving Health*, where Armstrong has happily introduced very similar ideas:

> What does not fade? the tower that long had stood
> The crash of thunder and the warring winds,
> Shook by the slow, but sure destroyer, Time,
> Now hangs in doubtful ruins o'er its base;
> And flinty pyramids, and walls of brass,
> Descend: the Babylonian spires are sunk;
> Achaia, Rome, and Egypt moulder down;
> Time shakes the stable tyranny of thrones,
> And tottering empires rush by their own weight;
> This huge rotundity we tread grows old,
> And all those worlds that roll around the sun,
> The sun himself shall die, and ancient night
> Again involve the desolate abyss‡.

I might select many more beauties from the *Sacred Theory of the Earth*. The passages I have quoted, however, show the general strain of the author, and it would be irrelevant amusement to pursue them.

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* *Spectator*, No. 146.

Attached to the English edition of Burnet's work, above referred to, is an "Ode to the Author, by Mr. Addison," in the ordinary fulsome style of that period. The following stanza is a specimen:

> Jamque alta Cœli mœnia corruunt,
> Et vestra tandem pagina, (proh nefas!)
> Burnette, vestra augebit ignes,
> Heu! socio peritura Mundo.

† *Burnet's Theory*, Vol. ii., p. 25.

‡ *Art of Preserving Health*, B. ii.

2058. A very different reasoner from Burnet was Woodward; he was nothing of a poet, and not much of a philosopher; he pretends to be a matter-of-fact man; but having collected a few observations respecting the contents of strata, hastily proceeded to the erection of a theory; "to build a ship," as Lord Bacon says, "with materials insufficient for the rowing-pins of a boat." Woodward observed the existence of fossil shells, and remarked that the lower strata of the earth's surface were generally harder than the upper, which were of more light and pulverulent materials: whence he concluded, that at the period of the deluge, the earth had acquired a new crust deposited upon it by the waters, in the succession of the specific gravity of the materials; the heaviest, coarsest, and hardest bodies forming what *to us* seem a nucleus, covered by finer and lighter deposits[*].

2059. About this time Leibnitz published his *Protogæa*[†]; he supposes the earth to have been in a state of combustion for many ages, and at length to have gone out for want of fuel. A glassy crust was thus formed, which gave rise to sand and gravel; other kinds of earth resulted from sand and salt; and as the globe cooled, the water which had before been kept in the state of steam, assumed fluidity, and, falling to the earth produced the ocean. The particulars of these notions are, of course, not worth reciting.

2060. Whiston[‡] having blended the follies of Burnet, Woodward, and Leibnitz, endeavours to conceal his imbecility under the lion's skin of mathematical calculation; and taking many things for granted, of which there is not the most distant probability, leaves us bewildered and perplexed; he is neither plausible nor amusing, and is best known as having called forth the libellous witticism of Swift.

2061. But there was a contemporary of Whiston, whose works deserve more attention; John Whitehurst[§], a native of Congleton, in Cheshire; he passed much of his time in Derbyshire, and investigated, with considerable ability, the stratification of that rich and interesting county; "hoping," as he expresses it, "to obtain such knowledge of subterraneous geography, as might be subservient to the purposes of life, by exposing new treasures which are concealed in the lower regions[‖]." In his inquiry into the original state and formation of the earth he has assiduously collected facts, among which his account of the strata of Derbyshire retains much value at the present day, though repeated investigations have since been made with all the advantages of modern improvements. And as to his theoretical views, I think it is scarcely going too far to say, that they are the best extant: for, unlike latter geologists, he first collected facts and then constructed his theories; and those who are unbiassed by speculative doctrine, and really think for themselves, will consequently accede to by far the greater number of his leading propositions.

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[*] Woodward applied the geological observations he had made in England to other countries. "I was abundantly assured that the circumstances of these things in remoter countries were much the same with those of ours here; that the stone and other terrestrial matter in France, Flanders, Holland, Spain, Italy, Germany, Denmark, Norway, and Sweden, was distinguished into layers, as it is in England, *&c. &c.* To be short, I got intelligence that these things were the same in Africa, Arabia, Persia, and other Asiatic provinces; in America," *&c.* See *An Essay towards a Natural History of the Earth and Terrestrial Bodies*, by John Woodward, M. D., *&c.* London, 1702.

[†] *Leibnitzii Opera Omnia.* Geneve, 1768. Vol. ii. p. 199.

[‡] *New Theory of the Earth*, &c. By William Whiston, M. A. 4th Edition, London, 1725.

[§] *The Works of John Whitehurst, F.R.S.*, London, 1729. "It is my intention (says Whitehurst, in his *Preface* to the *Inquiry into the Original State and Formation of the Earth*, to trace appearances in nature from causes truly existent; and to inquire after those laws by which the Creator chose to form the world, not those by which he might have formed it, had he so pleased."

[‖] Whitehurst particularly notices the similarity of succession in the strata of England; and in his description of Derbyshire, he mentions the resemblance of the toadstone to lava, and infers, from its appearance, situation, and effects, that it must have issued from below in an ignited state; that it must have been projected with great violence amidst the superincumbent strata. and that their displacements and irregularities are the consequence.

2062. But no one has proceeded to the forming of a theory of the earth with the pomp and circumstance of Buffon*. It merits attention, not on account of its accordance with present appearances, or as affording plausible solutions of observed phænomena, but from the eloquence with which it is adorned, the extent of information it displays, and the popularity it derived from these sources.

He supposes the planets in general to have been struck off from the sun by a comet; that they consisted of fluid matter, and thence assumed a spherical form; and that by the union of centrifugal and centripetal forces they are restrained in their present orbits. The earth gradually cooled, and the circumambient vapours condensed upon its surface, while sulphureous, saline, and other matters, penetrated its cracks and fissures, and formed veins of metallic and mineral products. The scorified, or pumice-like surface of the earth, acted upon by water, produced clay, mud, and loose soils; and the atmosphere was constituted of subtile effluvia, floating above all the more ponderous materials. Then the sun, and winds, and tides, and the earth's motion, and other causes, became effective in producing new changes. The waters were much elevated in the equatorial regions, and mud, gravel, and fragments were transported thither from the poles; hence, says Buffon, the highest mountains lie between the tropics, the lowest towards the poles; and hence the infinity of islands which stud the tropical seas. The globe's surface, once even and regular, became now rough and irregular; excavations were formed in one part, and land was elevated in another; and during a period of ages, the fragments of the original materials, the shells of various fish, and different other exuviæ, were ground up by the ocean, and produced calcareous strata, and other low-land depositions. These relics of marine animals we find at such heights above the present level of the sea, as to render it more than probable that the ocean once entirely overwhelmed the earth.

Of the phænomena I have hinted at, Buffon takes particular and extended notice, and draws from them a series of curious and minute conclusions; not, however, satisfactory or logical, inasmuch as many of the data they are founded upon are imaginary, not real. Every one who now contemplates the earth's surface, must trace upon it marks of the most dire and unsparing revolutions, which, from the present order of things, it appears impossible should re-occur, except by the united and continuous agency of the most active powers of destruction. This, says Buffon, arose from the soft state of the former crust of the earth; and those causes, now imbecile and slow in their operation, were then more effectually exerted, and results were obtained in a few years, for which centuries would now be insufficient.

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* *Histoire et Theorie de la Terre et des Epoques de la Nature.* 4 Vol. 8vo. Paris, 1800.

This amusing theorist next proceeds to contemplate the production of rivers, which he regards as having cut their own way to the ocean, as gradually wearing down the mountainous lands, filling up valleys, and choking their exits into the ocean by the transportation of finely-divided materials. Thus every thing is slowly returning to its former state; the mountains will be levelled, the valleys heightened, excavations filled up, and the ocean will again cover the earth.

I shall not enter into the various confutations of these speculative notions, nor dwell upon many modern theories to which they have given rise. Pallas, Kirwan, De Luc, and others, have animadverted upon, but can scarcely be said to have improved, Buffon's hypothesis; and as we set out with granting it to be the mere fabric of imagination, it would be folly to submit it to the solemnity of philosophic criticism.

2063. Many other theories of the earth I pass over in silence, as containing nothing not to be met with in some of the already mentioned cosmogonists. The authors have sometimes clothed their fictions in new dresses, or presented them under new forms; but, if we remove the mask, Burnet or Buffon are instantly recognised. Thus, in pretending to advance learning, they have rather obstructed it, and have accumulated hypotheses without enriching science. They deserve that censure thrown upon certain writers by Dr. Johnson, who calls them the "persecutors of students, and the thieves of time." Such at least I have found them.

There are other geological writers who have accumulated many interesting facts, and whose insulated observations are truly curious and valuable; but their general hypotheses are of so chimerical a cast, as rather to resemble Eastern allegories than European philosophy; they defy all criticism, and therefore lie out of our present track, which now leads us to review the prevailing theories of the present day. These are the inventions of Professor Werner, of Freyburgh[*], and Dr. Hutton, of Edinburgh[†], each of whom has been ably supported and elucidated by the proofs, illustrations, and comparative views of acute and eloquent controversialists[‡], and two sects have been formed, under the appellation of Wernerians and Huttonians. The disputes and differences of these contending geologists would now be prematurely noticed. They each profess to proceed, as rigidly as the subject allows, in the path of induction; to reject mere hypothesis, and raise their theories upon accumulated facts; and yet they arrive at conclusions diametrically opposite; upon which a clever writer remarks, "that among all the wonders geology presents to our view, the confidence of the theorists is by far the most unaccountable."

2064. The first principle of the Wernerian theory assumes, that our globe was once covered with a sort of chaotic compost, holding either in solution or suspension the various rocks and strata which now present themselves as its exterior crust. From some unexplained cause, this fluid began first to deposit those bodies which it held in chemical solution, and thus a variety of crystallized, or *primitive rocks*, were formed. In these we find no vegetable or animal remains, nor even any rounded pebbles; but in the strata which lie upon the crystalline or first deposits, shells and fragments occasionally occur: these, therefore, have been termed *transition strata;* and it is imagined that the peopling of the ocean commenced about this period. The waters upon the earth began now more rapidly to subside, and finely divided particles, resulting from disintegration of the first formations, were its principal contents; these were deposited upon the transition rocks chiefly in horizontal layers. They abound in organic remains, and are termed by Werner *floets* or *secondary rocks.*

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[*] *A Comparative View of the Huttonian and Neptunian Systems of Geology.* Edinburgh, 1802.

[†] *Theory of the Earth.* By James Hutton, M.D., F.R.S., Edinburgh, 1795. 2 Vols. 8vo.

[‡] *Illustrations of the Huttonian Theory of the Earth.* By John Playfair, F.R.S., &c., Edinburgh, 1802.

It is now conceived that the exposure of the *primitive transition* and *secondary* rocks to the agencies of wind and weather, and to the turbulent state of the remaining ocean, produced inequalities of surface, and that the water retreated into lowlands and valleys, where a further deposition took place, constituting clay, gravel, and other *alluvial* formations.

There are also certain substances which, instead of being found in regularly alternating layers over the earth, are met with in very limited and occasional patches. Rock-salt, coal basalt, and some other bodies are of this character, and Werner has called them *subordinate* formations.

Lastly, subterraneous fires have sometimes given birth to peculiar and very limited products; and these are called *volcanic* rocks.

Such is Werner's account of the production of rocks, which he arranges under the terms *primitive*, *transition*, *secondary*, *alluvial*, *subordinate*, and *volcanic formations.* A number of nice distinctions and accurate minutiæ of description attend this theory, which we cannot notice in this bird's-eye view, and which do not affect the general conclusions.

If we examine the stratification of our globe, we shall doubtless find that certain substances do occur in a certain order of arrangement, and that they appear to have been successively deposited, one upon the other, in the manner Werner and his disciples would have us believe; but when we more minutely examine the structure of the earth's surface, and the relations of its different strata, so many incongruities are discovered, and so much is at variance with their leading doctrines, that we are obliged to give them up in favour of views more generally applicable.

2065. Dr. Hutton gives a very different account of the present order of things. Looking upon the face of nature, he observes every thing in a state of decay; and as she has obviously provided for the regeneration of animal and vegetable tribes, so the philosophic mind will descry, in this apparent destruction of the earth's surface, the real source of its renovation. The lofty mountains exposed to the action of the varying temperature of the atmosphere, and the waters of the clouds, are by slow degrees suffering constant diminution: their fragments are dislodged: masses are rolled into the valley, or carried by the rushing torrents into rivers, and thence transported to the sea. The lower and softer rocks are undergoing similar, but more rapid destruction. The result of all this must be, the accumulation of much new matter in the ocean, which will be deposited in horizontal layers. Looking at the transition rocks of Werner, he perceives, that though not strictly crystalline, they appear made up of finely-divided matter, more or less indurated, and sometimes very hard in texture, and of a vitreous fracture; and that this hardening is most perceptible when in contact with the inferior rock, which often pervades them in veins, or appears to have broken up or luxated the superincumbent masses. According, then, to Dr. Hutton, the transition or secondary rocks of Werner were deposited at the bottom of the ocean in consequence of operations similar to those which are now active, and the primary rocks were formed beneath them by the action of subterraneous fires; their crystalline texture, their hardness, their shape, and fracture, and the alterations they have produced upon their neighbours, are the proofs of the correctness of these views. It is by the action of subterraneous fire, then, that rocks have been elevated, that strata have been hardened, and that those changes have resulted which an examination of the earth's surface unfolds. The production of soils, and of alluvial land, is considered as depending upon the same causes as those referred to in the other theory.

It will be observed that Hutton refers to fire as well as water for the production of our present rocks; the former consolidating, hardening and elevating, the latter collecting and depositing the strata. This system has been happily illustrated by many of the phænomena that occur among the mountains of Scotland, the birth-place of its inventor, and the seat of his speculations; it has been elucidated by the eloquent and philosophic pen of Mr. Playfair; and has received other advantages and aids, which the Wernerian theory has not enjoyed. But these circumstances must not be suffered to bias an impartial story; it is to facts we must attend, and upon them found our verdict.

Much as has been said upon the mischief of geological theories, which by some are represented as ingenious, though dangerous, fictions, no one can justly deny their importance and utility, as furnishing strong incitements to the labour of observation and experiment. He that has framed a theory is fond of searching for confirmations and he proceeds with a real enthusiasm widely distinct from the cold accuracy of the mere accumulator of insulated facts. In all physical inquiries, theory and observation should go together, like mind and body, the one guiding and directing the other. It is quite true that the impartiality of an observer may often be affected by system; but upon this it has been justly remarked by Mr. Playfair, that it is a misfortune, against which the want of theory is no security. The partialities in favour of opinions are not more dangerous than the prejudices against them; for such is the spirit of system, and so naturally do all men's notions tend to reduce themselves into some regular form, that the very belief that there can be no theory, becomes a theory itself, and may have no inconsiderable sway over the mind of an observer. Besides, one man may have as much delight in pulling down, as another in building up, and may choose to display his dexterity in the one occupation as well as in the other. The want of theory, then, does not secure the candour of an observer, and may greatly diminish his skill. The discipline best calculated to promote both is a thorough knowledge of the methods of inductive investigation, an acquaintance with the history of physical discovery, and the study of those sciences in which the rules of philosophizing have been most successfully applied.

SECTION II. *Of the Succession of Strata incrusting the Globe, and of the Stratification of Britain in particular.—Of Granite, and other primary Rocks.*

2066. THE terms primitive and secondary rocks, employed in the description of Werner's theory, were introduced into geology by Lehman*, a correct and sensible writer of the middle of the last century. He considered the crust of the earth as presenting three distinct series of substances. The first, coeval with the world, he calls primitive. or primary, rocks. The second series are of more recent formation, and seem to have resulted from some great catastrophe, probably the deluge, tearing up, and modifying the former order of things ; and the third class owe their formation to partial or local revolutions, as indicated by their structure and situation.

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* *Traites de Physique, d'Histoire Naturelle, de Mineralogie, et de Metallurgie.* Par J. G. Lehman : *traduits de l'Allemand.* Paris, 1759. "Les montagnes sont des élévations de la terre de différentes hauteurs, dont quelques-unes sont composées de parties dures, solides, et pierreuses ; d'autres sont composées seulement de parties terreuses ; quelques-unes ont été créés en même tems que la terre, d'autres ont été formées par des accidens, ou par des évènemens qui ont eu lieu, en différens tems."—Vol. iii. Sect. 3. "Il n'y a rien de plus naturel que de partager toutes les montagnes en trois classes. La première classe sera celle de montagnes qui ont été formées avec le monde. La seconde sera celle des montagnes qui ont été formées par une révolution générale qui s'est fait sentir à tout le globe. La troisième classe, enfin, sera celle de montagnes qui doivent leur formation à des accidens particuliers, ou à des révolutions locales." "Les montagnes de la première classe sont élevées, dont quelques-unes se trouvent isolées dans des plaines ; mais qui, le plus ordinairement, suivent une longue chaine et traversent des parties considérables de la terre. Elles diffèrent des montagnes de la seconde classe : 1. Par leur élevation et par leur grandeur, qui surpassent celles de toutes les autres. 2. Par leur structure intérieure. 3. Par les substances minérales qui s'y trouvent."—*Ibid.*

These passages are sufficient to show the merits of Lehman as an original and acute observer, and have furnished subsequent geologists with the foundations of their arrangements.

2067. In taking a general view of the substances which incrust our globe, for of its nucleus we know nothing, we perceive certain distinctions of texture and disposition, which are at once curious and important. The rocks which I have elsewhere called primitive, or primary, are generally found in huge masses or blocks, not regularly stratified*, and affecting in their fractures and fissures, a vertical arrangement. Sometimes they are of a perfectly homogeneous texture, commonly hard and durable, and sometimes composed of two or three ingredients blended together; they are generally crystalline in their texture, and usually constitute the loftiest mountains. The transition series of rocks of the Wernerian School, or those which they hypothetically deem next in point of antiquity to the primitive, are less lofty than the former; they, in many instances, present a slaty texture; they seem to have been deposited in strata or layers, and these are seldom either vertical or horizontal, but variously inclined to the horizon. The secondary rocks, or the more recent series, are nearly, if not quite horizontal in their position. In their texture they are soft, and consequently easy of decay, and they appear rather as mechanical deposits, than as chemical compounds which have resulted from fusion, crystallization, or solution. The wood-cut at the head of this Chapter may serve to give some idea of the relative heights and aspects of these three series of rocks.

These different series are tolerably regularly arranged in regard to each other. The primary rocks form the bases upon which the others rest; the transition are immediately recumbent upon these; and these are succeeded by the varieties of secondary rocks, and by their detritus constituting alluvial matter and soils.

2068. In selecting illustrations from nature of the different geological phænomena that come before us, I shall in all cases prefer reference to our own country; and I presume that it would, on the whole, be difficult to select a better spot for the study of geology than Great Britain. We have every variety of rock presented under its various aspects; and though in foreign climes nature may have more liberally dispersed the sublime, she has no where more instructively or delicately diversified the earth's surface than in the small space allotted to the British isles.

A section of the south of England, from the coast of Cornwall, for instance, in the west, to London in the east, will furnish a good exhibition of the phænomena of stratification to which I have just alluded. It will begin at the Land's-End, with primitive rocks, massive and amorphous. Upon this rest several species of transition rocks, especially slates of different kinds, having various inclinations; and these are succeeded by secondary strata, deviating more and more from the vertical, and acquiring the horizontal position; and ultimately we attain the alluvial matter upon which the metropolis stands. It is principally clay, and has once perhaps formed the mud at the bottom of a salt water lake†.

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* To this distinctive character there are, however, numerous exceptions; gneiss, mica slate, quartz, rock, and clay slate, exhibiting a distinctly stratified arrangement.

† Mr. Greenough's valuable Geological Map of England and Wales, and Mr. Smith's Geological County Maps, will be found very useful to the student; to whom I also recommend W. W. Phillips' *Selection of Facts*, &c., as an excellent abridgment of the important memoirs contained in the *Geological Transactions*.

Proceeding from London northwards, towards the Scotch border, the order of stratification is reversed; and traversing a highly interesting series of secondary rocks, we arrive in Cumberland at some of the primitive series. The whole arrangement is such as to include the highest and oldest rocks upon the west side of England, forming an interrupted chain extending from the Land's-End, in Cornwall, to Cumberland, and thence to the northern extremity of Scotland. So that the length of Great Britain, and its general shape, appear in a considerable degree dependant upon this chain of mountainous land, and upon two lower ridges, which extend in one direction from Devonshire, through Dorsetshire, Hampshire, and Sussex, into Kent: and in another, nearly from the same point, to the east of Yorkshire.

The western ridge is broken in upon in several places by plains and rivers, giving rise to so many chasms in the great chain.

In the Descriptive Catalogue of the Geological Specimens in the Royal Institution*, an attempt has been made to follow the natural succession of strata in Britain, and to show their successive alternations; and I trust that it will prove serviceable in connecting the following observations with their respective illustrative districts of our island.

2069. Of the primitive rocks†, one of the most abundant in nature, and the most useful in its applications, is GRANITE, so called from its appearing to be made up of a number of distinct grains or particles. Its essential component parts are *quartz*, *feldspar*, and *mica*.

2070. *Quartz* is the substance commonly called *rock-crystal*, and has already been described (1336). It is sometimes met with in mountain masses, which usually present a conical appearance. The quartz is milk white, and of a more or less granular texture. The Sugar-Loaf Mountains near Dublin, the Paps of Jura in Argyleshire, and some of the mountains of Sutherland and Caithness, present instances of this formation which is stratified in the island of Jura‡.

2071. *Feldspar*, the next constituent of granite, is a compound body, of which silica and alumina are predominant ingredients; it generally contains a little lime and potassa, and is often coloured by minute portions of oxide of iron§. Sometimes it is found crystallized, when it assumes the form of four and six-sided prisms, bevilled on the extremities; its usual colours are red, white, and grey. It is softer than quartz, but harder than glass, and is characteristically marked by fusibility before the blow-pipe.

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* *A Descriptive Catalogue of the British Specimens, deposited in the Geological Collection of the Royal Institution.* Longman & Co., 1816.

† In selecting specimens of rocks and strata for the geological cabinet, we should endeavour to show their recent fracture, as well as their weather-worn surface, which is generally easily attainable.

‡ *Geological Transactions*, ii. 450.

§ In a fine specimen of pale flesh-red feldspar, from the Alps, crystallized in the form of the oblique four-sided prism, I found the following constituent parts:

Silica	68.00
Alumina	20.00
Potassa	8.30
Lime	2.00
Oxide of iron	0.50
	99.00
Loss	1.
	100.00

Feldspar is a very important ingredient in many kinds of pottery; and the substance used by the Chinese, under the name of *petuntz*, is probably of a similar nature. The decomposing feldspar of Cornwall is abundantly employed in the English porcelain manufactories, and as it contains no iron, it retains its perfect whiteness. According to Mr. Wedgwood, it consists of

60 alumine
20 silex
20 moisture and loss.

There are some beautiful varieties of feldspar employed in ornamental jewellery, such as the *green* and *blue* or *Amazon-stone*, of Siberia and America; the *foliated*, *pearly*, or *resplendent feldspar*, called *adularia* and *moon-stone;* and the feldspar of the island of St. Paul, upon the coast of Labrador, distinguished by the property of reflecting very beautiful colours when the light falls upon it in certain directions. Feldspar is an important component of several other rocks besides granite.

2072. *Mica*, the third and last of the essential ingredients of granite, is a well-marked compound mineral, consisting principally of alumina and silica, with a little magnesia and oxide of iron. Its texture is lamellar, and it is easily split into thin, flexible, elastic, and transparent plates. It is so soft as readily to yield to the nail; it is sometimes met with crystallized in four and six-sided plates and prisms. Its usual colours are shades of brown and grey; sometimes it is red, and sometimes black. In some parts of Siberia mica is copiously quarried, and is employed as a substitute for glass in windows and lanterns. It has been thus used in Russian ships of war, where it has the advantage of not being shattered, like glass, by the discharge of artillery. The extreme tenuity of the plates into which it may be divided, and their elasticity, renders it very useful for the enclosure of objects to be submitted to microscopic inspection.

2073. Such are the characters of the components of granite; in some specimens of which they may be distinctly traced and separated from each other; but sometimes the particles are so small as to produce a compound, which to the unaided eye will seem almost homogeneous. We have, therefore, *fine* and *coarse-grained granite*. The former is abundant in Scotland, the latter in Devonshire and Cornwall. Indeed, the Cornish granite is remarkable for the well-defined and large crystals of feldspar which it contains, and which may be seen in many parts of London, where this rock has been used for paving, and where the crystals of white feldspar have become evident in the mass, from the constant attrition to which it has been subjected. It is of this stone that the Strand Bridge is mainly constructed. The colour of granite is principally dependant upon that of the feldspar it contains, though a dark mica will often give it a gloomy hue. It is commonly grey or reddish.

2074. There are two rocks very closely allied to granite, and usually associated with it; I mean slaty granite, or GNEISS, composed of precisely the same materials as granite, but slaty in its fracture, owing to the comparatively large quantity of mica it contains; and the other rock is a compound of mica and quartz; it has a slaty texture, and also derives its leading characters from the large quantity of mica it contains; it is called MICA SLATE.

2075. On the origin of granite geologists widely differ. As it constitutes the basis upon which all other rocks appear to lie, Werner has regarded it as the first formation of that chaotic rock-depositing fluid, in which he imagines the earth once to have been enveloped. But many peculiarities of granite have been adduced by Dr. Hutton, as contrary to such an opinion. If we examine a granitic district in nature, we shall observe, in regard to it, two leading phænomena. The one is that veins of granite frequently shoot from the great mass into the superincumbent strata. The other, that the bodies lying upon granite, especially if they be stratified, either bear evidence of having been broken up, dislocated, and penetrated by the granite, whilst in a fluid state; or they seem as if gradually elevated by some power which has thrown the granite up from below. So that, upon this view of the subject, the date of granite as far as concerns its present position, is posterior to that of the strata that rest upon it. They were first deposited, and the granite then erupted from beneath, and elevated the other strata, throwing them out of the horizontal, and giving them various inclinations to the horizon, or sometimes a vertical position. The Brocken Mountain in the Hartz Forest in Germany, St Michael's Mount in Cornwall, and the granitic district at Aviemore in the Scotch Highlands, will furnish illustrations of this subject. The first I select as being, at the same time, one of the favourite proofs with the Wernerians of their master's theory, while the Huttonians may regard it no less favourable to the truth of their views.

Of this mountain the peak is granite, and upon it are regular layers of other rocks, the dip or inclination of which is regulated by the surface of the central granite. In inspecting a section of the Hartz mountain, it will, I think, hardly be denied, that the appearance is rather in favour of the elevation of the strata, by the eruption of the granite, than of the original deposition of the granitic nucleus, and the successive subsidence of the other strata upon it.

At St. Michael's Mount, in Cornwall, a schistose, or slaty, rock, is invaded by a mass of granite from beneath; veins of the latter penetrate the former, which is hardened, and broken, apparently by the force with which the granite has been protruded. Indeed, the whole granite district of the west of England, beginning at Dartmoor, in Devonshire, and extending to the Land's End, in Cornwall, presents appearances, which are no way so well accounted for as upon that hypothesis which considers the granite to have been thrown up from below in a fused state, and to have forced its way through the superincumbent strata. There are four granitic summits in the promontory of Cornwall, all probably connected with each other, and with that at Dartmoor; and the surrounding country is principally clay slate, which every where inclines to the granite, in the same manner as the strata of the Brocken, in the Hartz Forest.

In the hill at Aviemore, to which I have alluded, veins of granite are seen penetrating the slaty rock in all directions; and upon the weather-worn side, facing the north-east, a large vein of granite may be perceived, widest at bottom, running nearly perpendicular, and enlarging into a mass, or stratum, of granite, between the schistose layers.

Such, then, is the appearance of granite, and such the arguments of the Huttonian geologist concerning its origin. I have mentioned that the superincumbent rocks are frequently penetrated by granite veins, and it is obvious that every vein must be of a date posterior to that of the body which contains it; and further, as the veins are often observed to proceed from the main body of the granite, into the superincumbent strata, it may be argued, *that the mass of granite, and the veins proceeding from it, are coeval, and both of later formation than the immediately superincumbent strata.*

Veins of granite, however, are frequently discovered, which cannot be traced to any original mass, or mountain; they seem to be insulated, as it were, among other strata. This is the case at Portsoy, and in Glentilt; and in some of the Western Isles of Scotland, especially Tiree and Coll; and is also observed in many parts of Cornwall. Dr. Hutton, from collateral evidence, conceives that these are always united to some granitic mass, though too deep, or at too great distance, to be traced and discovered.

It may now be asked, how the pupil of Werner accounts for phænomena of this kind? I have already said that he regards granite as having been deposited before all other rocks, though its irregularity and its general want of stratification are decided objections to such an idea, and that the other substances were precipitated upon it in the order we find them. In these strata, cracks and fissures occurred, and a new deposition of granite took place from the chaotic fluid, confined to the said cracks and fissures, and producing the appearance of granitic veins; and the hardening of the neighbouring rocks, referred by the Huttonians to the heat of the injected granite, is accounted for by the infiltration of the aqueous solution, which has, as it were, lapidified the softer materials. Now, though we may imagine granite to have been in igneous fusion, we cannot easily conceive it susceptible of aqueous solution; and if so dissolved, why should its second deposition have been confined to the cracks and fissures? Why should it not have formed a new stratum? With these facts before us, it is useless to enter into further comments, and we can only embrace that hypothesis, (for, after all, it is but hypothesis,) which appears best supported by evidence derived from actual observation[*].

2071. The aspect of a granite district in nature is subject to variation; it, however, exhibits traits sufficiently peculiar, which are readily recognised by the traveller in his approach to it.

In Cornwall, and in some parts of Ireland, especially in the county of Donegal, the granitic rocks are marked by the bold and abrupt precipices which they present to the attacks of the ocean; and by the barren and dreary aspect of the inland plains that seem like fields, in which blocks of the stone have been torn from their beds, and indiscriminately scattered over the moss-grown surface. The elevation of these districts is not considerable, the granite is coarse grained, and splits into immense blocks, separated from each other by natural seams, and appearing like the ruins of edifices constructed by a giant race. In other cases, granite forms irregular and broken peaks, of prodigious elevation, and does not split into the blocks and masses just alluded to. This is the case in the Alps and Pyrenees, in the highest Scotch mountains, in the Hartz, and in the Tyrol.

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[*] Some have regarded granite as a congeries of crystals of mica, feldspar, and quartz accidentally blended and united; the inspection, however, of the rock, clearly proves that all its materials have been together in fusion; for we find in some granites the quartz impressed by the crystals of feldspar, and in others the feldspar receives impression from the quartz. Dr. Hutton has looked upon this as demonstrating the igneous fusion of granite, for, (says Mr. Playfair,) "had the materials been dissolved in water, one kind of crystal ought not to impress another, but each enjoy its own peculiar shape." This, however, I do not hold to be sound argument

In Asia and Africa granite constitutes the Uralian, Altaian, and Himáláyán chains, and the Atlas mountains; and in South America, the lofty ranges of Cordilleras are chiefly of a similar description. The wood-cut at the head of this section shows the appearance of the alpine and of the massive granite. The sketch is taken from that of Mont Blanc, and of the Land's-End, in Cornwall.

2077. Some kinds of granite are prone to decomposition, crumbling down into a fine clay containing siliceous particles: this probably arises from a peculiarity of the feldspar, afterwards to be noticed. In general, granite is the most durable of nature's productions, and long resists the destroying hand of time; as a building material, therefore, granite is almost unrivalled: and, though in common cases its extreme hardness is against its employment, its use should be enjoined for public edifices. Dublin furnishes some noble examples of buildings constructed of granite, which is there procured in the immediate vicinity of the city, and of a very beautiful kind.

In Wales there is very little granite; in the north of Scotland it is abundant; and in England it occurs in Cornwall, Devon, Westmoreland, and Cumberland. It is also met with in smaller quantities in Worcestershire, at the Malvern Hills; and in Leicestershire, in Charnwood Forest.

2078. Although granite probably exists in great abundance below the earth's surface, the quantity visible above ground is comparatively small, perhaps not amounting to a hundredth part of the other primitive and transition rocks. In some parts of Scotland the granite superficies, however, is very considerable, and much exceeds the limits assigned to it by Dr. Hutton. Upon this subject a very acrimonious controversy arose between Dr. Hutton and Mr. Kirwan; the general statements, however, of the former, in this and other cases, commonly make much nearer approach to truth than those of the latter; but as human reason is not infallible, he who always contradicts must sometimes be right, and thus the mere cavilling disputant may occasionally discover the errors of the slow and cautious observer of nature.

2079. To the class of massive unstratified rocks belongs PORPHYRY, a substance which is ranked by Werner among the primitive formations. Its essential constituent is feldspar; and genuine porphyry may be defined as massive feldspar, containing embedded crystals of the same substance. Any rock including distinct crystals of feldspar, is called *porphyritic*, as *porphyritic granite*, &c. The colour of porphyry, which is usually reddish, brown, and green, is principally derived from the base, or paste including the crystals. The common aspect of porphyry is that of blocks and masses, not very unlike some of the varieties of granite, but its fragments are generally smaller, and are in a more decaying condition. Porphyry is an extremely durable material for architectural purposes, and as such was highly esteemed among the nations of antiquity. It is met with in many parts of Britain: and in the north, the porphyry districts are of singular grandeur, as at the base of Ben-Cruachan, on the banks of the Awe; and amidst the precipices of Ben-Nevis, the highest of the British mountains.

The British porphyries are many of them of great beauty, and might well be substituted for all ornamental purposes, for the more rare and expensive foreign varieties.

2080. Granitic rocks frequently contain a large proportion of *hornblende*, a mineral of a greenish black colour, which sometimes forms prismatic crystals; it consists of silica and alumina, with magnesia, and appears to derive its colour from oxide of iron, of which it contains from 20 to 30 *per cent.* Hornblende sometimes passes into mica; and if the component parts of the two bodies be compared by analysis, the principal difference will often be found to consist in the excess of iron in the former.

These aggregates are termed SYENITES, or *syenitic* rocks, and are of various hues, according as one or other of the constituents predominates. Sometimes the place of the quartz is wholly occupied by hornblende, and the rock is principally an aggregate of feldspar and hornblende. The term *syenite* is derived from Syene, in Upper Egypt, where this rock is plentiful and was used for architectural purposes by the Egyptian and Roman sculptors. The aspect of syenitic rocks is allied to that of granite and porphyry. They may be observed rising from the slaty district of St. David's in Pembrokeshire; and in Cumberland, near Wastdale and Buttermere. A beautiful syenite is noticed by Mr. Bakewell, as occurring in Leicestershire, at Markfield-Knowle, a hill on Charnwood Forest. Syenite very often contains magnetic oxide of iron.

2081. Another substance belonging to the class of rocks we are now describing, is SERPENTINE; its appearance is singularly picturesque and beautiful; and it forms a delightful contrast to the sublimity of granitic districts. Serpentine has its name from the variety of tints which it exhibits, such as bright red, green, brown, yellow, and their various shades, and it often is prettily traversed by veins of a soft substance, to which the term *steatite* or *soapstone* has been given (698)*.

Some of the varieties of serpentine admit of a tolerable polish, and such are very desirable for many ornamental purposes.

Serpentine is seen in Cornwall in characteristic beauty, forming part of the Lizard promontory on the southern coast of the county, where its general aspect is shown in the following sketch. It appears in variously shaped and coloured blocks and masses; it forms natural arches, columns, and caves; and the district is of very singular interest from many concomitant circumstances, especially from the blocks of porphyry upon which the serpentine is incumbent, and the veins of granite associating with those of steatite, which pervade it.

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* Serpentine has been repeatedly analyzed; but the results are very discordant; no doubt owing to the indeterminate nature of the rock. See JAMESON's *Mineralogy*, 2d. edit., Vol i., p. 509. Its principal constituents appear to be silica, magnesia, oxide of iron, and a little carbonate of lime. See the analyses of *Serpentine*, given above (1410).

Serpentine is met with also in the Isle of Anglesea, upon the northern coast near the celebrated Parys Mine. Some of the serpentine of this district is of more brilliant colours, more hard and translucent than the ordinary serpentine; it belongs to the species called by mineralogists *noble serpentine;* the same rock occurs at Portsoy, on the Murray Frith in Banffshire, where it is associated with granite.

The composition of serpentine, as relates to its proximate components, has been variously described. It is generally so fine grained as to appear of an uniform texture; but in Cornwall a coarsely aggregated rock, consisting of *feldspar*, *talc* and *schiller spar*, may be traced passing into the fine-grained serpentine. I have already alluded to the nature of feldspar. *Talc* is a body somewhat resembling mica in appearance, but the plates into which it is divisible are not elastic. Its usual colours are various shades of green. It consists of nearly equal parts of silica and magnesia, with a little lime; not more than six *per cent.* It is met with in small tabular crystals.

Schiller stone, or *schiller spar*, is a term from the Germans, implying glistening or changeable spar: it is one of the varieties of *diallage* of the French authors; it is a silico-ferruginous fossil, containing

44	silex
24	iron
18	alumina
12	magnesia.

Its colour is dark green: its usual lustre is semi-metallic, varying according to its position in regard to incident light.

Steatite is a substance of different tints of grey and green, and from its very singular unctuous feel has been called *soap-stone*. It is somewhat abundant in the serpentine of Cornwall, one of the masses of which is called the *soapy rock;* it is here carefully collected for the porcelain works of Worcester and Swansea, in which it forms a very important ingredient. It also occurs in the serpentine of Banff. According to Klaproth, Cornish steatite consists of

Silica	45.00
Magnesia	24.75
Alumina	9.25
Iron	1.00
Potassa	0.75
Water and loss	18.00
	98.75[*]

2082. **Marble** (643) is the last of the rocks belonging to the class I am now describing. It is also very abundant in the secondary rocks, but its characters are there different. Among primary rocks, marble is associated with mica slate, gneiss, serpentine, and quartz rock, and it differs from marble belonging to other rocks, in its granularly foliated texture and in the absence of organic remains. The most esteemed varieties are perfectly white and free from veins; somewhat translucent, and susceptible of a good polish. These marbles are imported for ornamental purposes, especially for those of the sculptor. Nearly all the sublime works of the Grecian artists were sculptured in the marble from the isle of Paros in the Archipellago, and from the Pentelic mountain near Athens; but the marble of Carrara is now in highest estimation, and is almost exclusively used by the European sculptors of the present day. Of the coloured varieties, that of the isle of Tiree is extremely beautiful; it is of a pale red, spotted with green hornblende. Marble is found in several parts of Scotland, and in some places of characteristic beauty, and alternating within small limits, with other rocks. Dr. Mac Culloch, in his *Sketch of the Mineralogy of Sky*[†], has described several beautiful varieties found in that island, and has adverted to the œconomical uses to which they are applicable. In Inverary park primary marble may be seen in contact with mica slate and porphyry. Serpentine and marble are sometimes blended together, and they then form a valuable compound for ornamental purposes, which has been called *Verd Antique*. In the serpentine of Anglesea, patches of marble are found which much enhance its beauty.

A very remarkable marble quarry is that of Icolmkil, or Iona. Gneiss rocks constitute the leading feature of this island, but at the south-west point is a bed of marble, about 40 feet wide bounded by vertical walls of hornblende rocks[‡]. Near it is a mass of hornstone, and above the whole protrudes an immense vein of granite, surrounded

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[*] Vide Klaproth's *Beitrage*, V. Band, S. 24.

[†] *Geological Transactions*, iii. p. 1.

[‡] The marble is of the species called *dolomite* (698), distinguished from the true primary marble or granular lime-stone, by the tardy effervescence excited by pouring muriatic acid upon it, and by its containing magnesia; it is also finer grained, and its fracture more splintery, than that of common marble. The dolomite of Iona yielded to Mr. Tennant,

Carbonic acid	48.82
Lime	31.12
Magnesia	17.06
Insoluble matter	4.00

Phil. Trans. 1299.

The dolomite of the Apennines yielded to Klaproth,

Carbonate of lime	65
Carbonate of magnesia	35

Beitrage, B. 4, S. 215.

by the marble, but from which it has been loosened, so as just to admit a person to pass between the two walls. That they have once been in contact, is proved by the granitic protuberances having correspondent indentations in the marble, and *vice versâ.*

2083. We have now considered a highly important series of rocks, and have enumerated their characters as insulated individuals. As a class they present analogies which distinguish them from their superincumbent neighbours, and give them the stamp of a peculiar and distinct formation, either formed before organic beings, or under circumstances which have destroyed such remains.

In these rocks we seldom observe any regular stratification; they are mostly constituted of amorphous, irregular, and various masses, and present no appearances of having been deposited from water. They are crystalline aggregates; and they are deeper in their situation than other rocks, which always appear incumbent upon them, and often elevated or heaved, as it were, by their operation.

They often break through the beds, or layers, that cover them, and rise to a very great elevation, forming the summits and peaks of the loftiest mountains. In England they are comparatively rare; in Cornwall there is abundance of granite, but it rises to no great height. Granite and its associates are found in Cumberland, but they are sparingly scattered over the county; and the romantic and picturesque aspect of the hills is chiefly derived from other species of rocks. In Wales, the primary rocks are uncommon, and I know of no granite; but there is a portion to be found in the centre of Anglesea, near Gwindy, where its associations merit notice.

In Scotland, the districts composed of primitive rocks, and presenting their various aspects, junctions, and transitions, are full of grandeur and interest. Travelling northwards from Edinburgh, we enter upon mica slate at one of the Highland passes, and crossing the Grampians, find their principal summits of the same materials. From Loch-Tay to Killin the same rocks continue, with beds of limestone. Ben-More is a mica slate rock, of exceeding grandeur: it rises to about 4000 feet above the sea's level, and is thickly intersected with quartz veins. Ben-Lawers, to the North of Loch-Tay, is of similar composition; it is chiefly gneiss, associated with mica slate and quartz; and the same substances are found at Crag-Caillach, and Schehallion, and contribute to the magnificence of the celebrated pass of Killikrankie, between Dunkeld and Blair in Athol.

I have thus represented the highest mountains in Britain as composed of granite and its associates; but these are mere trifling protuberances upon the earth's face, when compared with the exceeding heights of the Alpine chain, or the yet more elevated mountains of South America, and of Asia, which consist of the same materials. Ben-Nevis, the loftiest of the British mountains, is situated in the south of Inverness-shire, and is 4370 feet high. Cairngorm in the same county, is 4050 feet high. Mont Blanc, in Switzerland, has its peak elevated 15,600 feet above the level of the sea; it is the highest mountain of Europe; Chimboraso, the highest summit of the Andes, is 20,280 feet above the sea's level; many of the peaks of the Himâlâyâ chain are as high, and the loftiest appears to exceed 25,000 feet*.

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* See an article on this subject in the sixth Volume of the *Quarterly Journal of Science and the Arts*, p. 55.

The reason why these excessive elevations present nothing but primitive rocks, and especially granite, (excepting, indeed, where they are volcanic) may not at first appear quite obvious, for in the low lands the primitive are generally covered by secondary strata, which were also once probably incumbent upon their loftiest summits. It is likely that the destructive agencies of the elements have been so powerfully exerted in these elevated and unprotected regions, that the secondary rocks have yielded to their unceasing attacks, and have been carried towards the valleys by the rills and torrents, while granite and its durable accompaniments have more obstinately opposed the inroads of such resistless assailants.

2084. At the same time, however, it will seem probable that the granitic mountains have themselves suffered tremendous degradation, and that at a former period their summits were beyond their present elevation. All this will appear more clear when the general *characters* of mountain chains, and the phænomena of their decay, are *taken* into the account. But several circumstances present themselves to the most superficial observer, which in a language that it is impossible to misinterpret, announce the influence of destructive agents upon these apparently invulnerable materials. Prodigious masses of granite are often found among the secondary strata that form the valleys under primary mountain chains; they are insulated and unconnected with any general mass of the same material; and the more distant they are from the granite range, the more they are rounded and smoothened upon the surface. Of this description are the boulders, or blocks of granite, observed by Saussure upon the east side of the lake of Geneva. One of these, called *Pierre de Gouté*, is ten feet high, with an horizontal section of 15 feet by 20. In the valley of Chamouny, several similar blocks have fallen from the Aiguilles. Some of these have been transported between 30 and 40 miles, and as several mountains and valleys are now interposed, their transportation must have taken place at a very remote date*.

In the glen which separates the Great from the Little Saleve, there are many granite boulder stones strewed over a calcareous plain; and of these several are supported upon a short pillar of limestone, resulting from the protection afforded to the calcareous rocks by the harder boulder, so that the height of the column becomes a measure of the wearing away of the surrounding country. This appearance has induced Saussure to assert, that these stones are now in the very situation where they were left by the great aqueous torrent, or debacle, which tore them from their original bed, and brought them down from the high Alps; a conclusion, however, as Mr. Playfair has remarked, not altogether warranted by the fact. In some of the recesses of the the Jura there are large, and somewhat angular, blocks of granite which have evidently been deposited in their present situations at very remote periods, the surrounding and impending heights being composed of limestone rocks, which form an ampitheatre round the present valleys. In the neighbourhood of Neufchatel, too, there is an enormous insulated mass of granite: it is as large as the celebrated foundation of the statue of Peter the Great, erected at Petersburgh by Catherine II., which is composed of a boulder, or detached block of granite, found in the bay of the Gulf of Finland, whence it was transported to the capital; its length was 42 feet, its breadth 27 feet, its heighth 21 feet*.

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* See Dr. Kidd's *Geological Essay*, Chapter. xviii., which contains an account of the most remarkable boulders.

In the Isle of Arran, an immense block of granite is found upon the shore, not only three miles from the nearest granite rock, but having also a bay of the sea intervening; and several similar instances might be adduced, proving the great ravages that have been committed upon even so hard and unyielding a body as granite. We shall not, then, be suprised that the same agents, acting upon softer materials, have made more successful depredations; and have, in many instances, completely denuded those granitic surfaces, which were once clothed by secondary strata.

2085. In Cornwall, granite is sometimes of very rapid decomposition, and the streams which traverse these districts deposit a finely-divided earthy matter, resulting principally from the feldspar, and much used in the potteries. Carglaise tin mine is situated in a decomposing granite of this kind, and presents a spectacle highly worthy the attention of the curious. The mine is a vast chasm in the granite rocks and exposed to the day. The tin ore and shorl rock traverse it in abundant veins, and the surrounding peaks strongly remind the beholder of a miniature representation, or model of the Alps. Possibly the rapid decay of the granite here depends upon the quantity of alcali contained in its feldspar.

Dr. Mac Culloch, in a dissertation on the granite Tors of Cornwall, published in the *Geological Transactions*, has made some interesting remarks upon the peculiarities which they present, and which have given rise to much idle and ignorant speculation. A very remarkable Tor is the *Cheese-wring*, upon an eminence near Liskeard. It is a cairn consisting of five stones, of which the upper ones are larger than and overhang the lower, the whole pile being 15 feet high. The stones of which it consists are yielding to the weather most rapidly at their angles and edges; they are thus becoming rounded, and approaching that tottering state which will soon hurry them down the precipice to their former companions in the plains below.

This tendency of square blocks of stone to become spherical, independent of friction, is productive, in other cases, of very curious consequences, and has often been considered as demonstrating the agency of streams or currents, by which the masses have been transported from distant regions. The present Tor has, by some antiquarians, been considered as a druidical statue of Saturn. The same cause appears to have produced the celebrated Logging-stone.

2086. Before we quit the subject of primary rocks, it will be right to mention a district of Britain, which, for grandeur of scenery and geological interest, can, I think, scarcely be surpassed. I allude to the country between the eastern extremity of Loch-Ness and Fort-George, and especially to the rocks over which the river Fyers pursues its turbulent and winding course.

These are seen in characteristic grandeur in the neighbourhood of the small inn called the General's-hut, and the scenery becomes more and more impressive and interesting until we arrive at the celebrated falls of the river. I should call the rock a *granitic breccia*, or *conglomerate;* it appears made up of numerous angular fragments of granitic materials, held together by a siliceous cement, and the aggregate is of extreme hardness and durability; masses resembling jasper and agate may also be observed in it. Dr. Garnet compares the cement, or basis of the rock, to a *lava* of a reddish hue; and a common observer would consider the whole as fragments of granite which had been united by semi-fusion, or softened and glued together, as it were in the fire. The general aspect of the surrounding scenery is such as to impress the mind with the idea of some vast convulsion of nature having torn the rocks asunder, and shattered them into gigantic fragments; rugged crags and abrupt precipices present themselves on all sides, and the river rushes with tremendous impetuosity through deep and obstructed chasms. A rude bridge is thrown over the upper fall, whence the spectator beholds the waters of the Fyers, at the distance of 200 feet beneath him, rushing into a cavity of 70 feet in depth, whence they again emerge in perfect stillness, and, running over an uneven and fragmented channel, approach the lower or grand fall. Here the waters, previously pent up and exasperated, suddenly discharge all their violence, and are lost in a deep abyss. The depth of the chasm in which the river flows is 400 feet, and it bursts forth in an unbroken stream, constituting a fall of 212 feet perpendicular height. The rugged irregularities of this district, the fragments that lie thickly strewed upon the sides of its mountains, the caverns that abound in its rocks, and the perpendicular precipice of the great cascade, considered conjointly with the peculiar texture and composition of the materials that form it, present many objects worthy the attention of some geologist, and may be regarded as recording some great natural convulsion, which has not only broken up and reunited certain primary rocks, but has again disturbed their tranquillity, and thrown them into the stupendous confusion they now exhibit.

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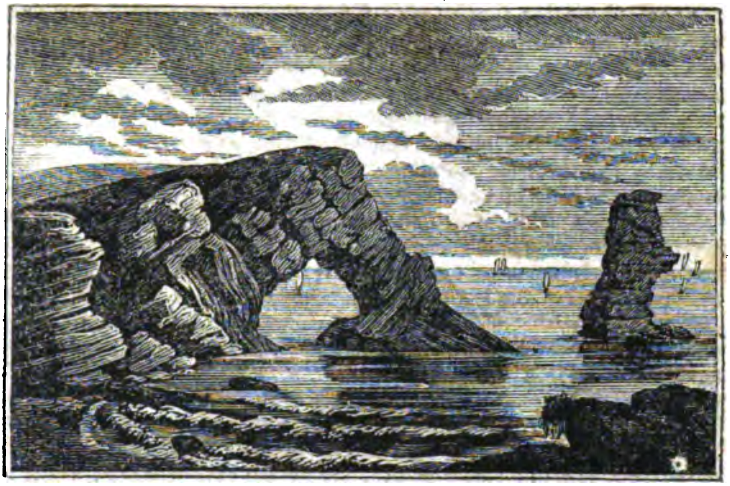
* See the *Relation*, par le Comte Marin Carburi de Ceffalonia, &c. Paris, 1777.



SECTION III. *Of Stratified Rocks, and of the Transition and Secondary Formations of Werner.—Rock-salt, Coal, Alluvial Matters, Basalt.*

2087. WE now descend from the primitive, to the *transition rocks* of Werner; these are more particularly the *stratified rocks* of the Huttonian geologists, and they are distinguished by several well-marked characters from the unstratified and primary rocks.

One leading and general circumstance may be observed in regard to them, which is, that they never attain the great elevation of the primary bodies; this has been elsewhere referred to the comparative readiness with which they yield to the assaults of decomposition and disintegration.

The highest known mountains in the world are those of Thibet, constituting the Himálâyân chain. They are alluded to by Col. Kirkpatrick, in his *History of Nepaul*, and an extended and interesting account of them has been published by Mr. Colebrooke, in the *Asiatic Researches*, Vol. xii.

Of this chain, the highest peak, covered with eternal snow, is called Dwawala-giri, or White Mountain; it is the Mont-Blanc of the Indian Alps, and rises to the astonishing altitude of 26,462 feet above the level of the plains of Gorakh'púr; or, upon the lowest computation, 26,862 feet above the level of the ocean. This is about 6000 feet higher than Chimboraso, 11,000 feet higher than Mont-Blanc, and 22,000 feet higher than the most elevated peak of the British dominions, which, indeed, makes Ben-Nevis seem very insignificant, though its summit is close upon the verge of perpetual snow in this climate. There can be no doubt that the lofty peaks of the Thibet chain are granite, though we learn that the hills which border them are secondary, and contain remains of spiral shells. The elevation of secondary rocks will, in a great measure depend upon that of the primary materials beneath them; thus, in the Andes they attain 12,000 feet, in the Alps 7000, and in this country not more than 3500.

2088. In respect to the original formation of secondary rocks, the notions of the Wernerians and Huttonians are not so widely different as we have found them formerly; they both agree that they are depositions from water; but how, then, have they lost their necessary horizontality, and acquired positions more or less inclined, or even sometimes vertical? Dr. Hutton conceived they were elevated and hardened by the throwing up of the primary or unstratified rocks from below, in the state of igneous fusion. It was once a great difficulty to imagine a combustible which should thus furnish fuel to melt these immense masses of primary materials, and to conceive the real cause of that expansive power of heat which Dr. Hutton always flies to. But the discoveries of Sir H. Davy, concerning the true nature of earthy bodies, have furnished unexpected evidence in defence of these apparent incongruities of the Huttonian doctrines, and it is bestowing no small praise upon a theory, to allow that it is strengthened by the progress of knowledge, and elucidated by the advances of *experimental* research. However, that these elevating powers do *exist*, is proved by the sudden throwing up of a hill in the bay of Naples, which was raised 1000 feet in a single night*, and by the appearance of a new island at the Azores, in water between 50 and 60 fathoms deep†. We must afterwards refer to the *cause* of these phænomina. At present possession of the fact is the main requisite. In the Neptunian system, it is conceived that the position of the strata has depended upon the ground they have been deposited upon, and that they have partly crystallized, and partly subsided, upon the inclined, or nearly vertical, sides of primary rocks; or that the falling in of caverns has occasioned their present irregularities; but, when we *observe the mischief* which the primary rocks seem to have done the *secondary, and when* we take into the account all the phænomena of granite veins, *before* discussed, I think that he who is not unduly biassed, will feel inclined to acquiesce in the Huttonian interpretation. It is probable, then, that the materials of the transition rocks, or, as I would rather put it, of those secondary and stratified rocks which are immediately incumbent upon the unstratified primitive rocks, are derived from the *destruction* of a former order of things; that they have been delivered *into the* ocean by the rivers, that they have covered the bottom of the sea, and have been hardened, elevated, and traversed by the eruption of granitic and other substances belonging to that class, from the bowels of the earth.

2089. The next peculiarity of the secondary rocks that presents itself, is their containing fragments, pebbles, and organic remains; whence cosmogonists have framed sundry conclusions concerning the particular period of their formation, which it will be unwise and useless here to discuss. At the same time, the presence of bodies which once belonged to the organized kingdoms, but which, although still retaining their original forms, are completely fossilized, furnishes us with many interesting conclusions, and holds out to the inquisitive unfailing matter of useful discussion. In the oldest secondary rocks fragments are often found, and rounded pebbles, whence we learn their origin from former rocks. Upon these, beds occur which contain remains of shells, corals, and fish, all of marine origin, and oftentimes the races are extinct. Approaching the newer rocks, relics of quadrupeds, now no longer known, are observed; and, following the deposition of strata, we ultimately arrive at remains of lizards, crocodiles, elephants, deer, and some other animals; and we occasionally discover districts containing land and sea-shells in alternating layers.

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* See Sir W. Hamilton's account, in the *Philosophical Transactions*, 1771.

† *Philosophical Transactions*, 1812. See Dr. Kidd's *Essay*, Chap. xxvii.

I merely make allusion to these facts, to show how curious and new is the field of inquiry, which modern geology has opened. It has taught us that whole races of animals have been swept from the earth's surface; that not only species, but likewise genera, have become extinct; that fresh water and dry land existed before the formation of many of our secondary strata; that oviparous quadrupeds began to exist along with fish, nearly at the commencement of the secondary formations; that mammiferous sea animals are of more ancient formation than land animals; that a few of those now known, existed towards the termination of secondary formations, but that by far the greater number are of later date, and probably contemporary with the present order of the earth's surface, for their bones are only discovered in very recent depositions, and are in a state of inferior preservation to those of more ancient date; and, lastly, it is to be observed that no fossil human remains have yet been found.

Such are some of the topics which this part of geology presents for consideration, and which show us that the earth is indeed "as a book, in which men may read strange matters." Though the existence of fossil remains must have been noticed from the earliest ages, the philosophical discussions to which they have given rise are of very modern date, and the merit of fixing the geologist's attention upon them, as recording certain revolutions of the globe, belongs chiefly to Cuvier.

Further, to promote attention to the nature and arrangement of the secondary rocks, it may be suggested that they are the chief repositories of metallic substances; and that, by their decomposition and decay they furnish the principal materials of the soil in which the vegetable has its habitation, and consequently upon which the existence of animals ultimately depends.

2090. Of the secondary rocks, CLAY-SLATE may be first noticed; it is extremely abundant, and generally immediately incumbent upon the primary series. It is often micaceous near the junction, and we frequently observe it fragmented, and penetrated by quartz, or feldspar, or mica, or by granite itself. Before the blow-pipe, it fuses into a black mass; its usual colours are various shades of grey, and it is generally so soft as to yield to the nail. Siliceous and argillaceous earths, and oxide of iron, with a little lime and magnesia, are its principal ingredients*. The varieties of slate are applied to various useful purposes: that which is easily separable into thin plates, compact, sonorous, and not injured by the application of a moderate heat, is em-

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* I obtained, as the results of the analysis of a specimen from Luss, near Dumbarton, the following component parts:

Silica	48
Alumina	28
Magnesia	5
Lime	2.5
Oxide of iron	10
Loss	6.5
	100.0

ployed for roofing houses. London is chiefly supplied from Bangor, in Caernarvonshire; and from the neighbourhood of Kendal, in Westmoreland; there are also very large quarries at Easdale, in Argyleshire; according to Mr. Jameson, five millions of slates are there annually manufactured, which gives employment to 300 men. There are several slate quarries of note in Dumbartonshire; one ought particularly to be mentioned, at Luss; it is of geological interest, and commands a captivating view of the lake, and the neighbouring mountains. Here the clay-slate rests upon mica slate; the former is of a purplish tint penetrated by veins of pink carbonate of lime, and of quartz; the latter is very remarkably contorted.

2091. Other varieties of clay-slate are used for writing-slates, slate-pencil, *&c.*; and where slate is very abundant, we observe it employed for monumental tablets, pavements, and walls. Crystals of *iron* pyrites, and some other extraneous bodies are not rare in *slate; these* generally render it unfit for the applications I have *alluded to.* *Slate* often contains fragments of other rocks, embedded masses, and nodules of various kinds, frequently pebbles, and occasionally a few impressions of shells; it also often derives a green colour from the presence of a mineral called *chlorite*, consisting of oxide of iron united to siliceous and aluminous earths. The slates containing embedded matters are called *grauwacke-slates*, or, when of a less slaty fracture, simply GRAUWACKE, a substance which is abundant in this country.

2092. The slate district of England is of considerable extent, and neither wants sublimity nor grandeur; it follows the great primary chain which I before alluded to, as running north and south upon the west side of England; in Cornwall the slate is *seen immediately incumbent* upon granite, and the slaty districts form *very beautiful scenery* upon many parts of the coast. The term *killas* has been *applied to* it by the miners. Nothing, I think, can exceed the scenery about Looe, Fowey, and the country between it and Falmouth, and upon the north coast Tintagell is yet more remarkable.

There is some grauwacke in many parts of Cornwall. The best marked specimens I have seen, are from Mawnan, near Falmouth, where it alternates with clay slate.

2093. The slate district of Wales is of singular interest and magnificence, as those will acknowledge who have visited the chain of mountains, including Snowdon, Plynlimmon, and Cader Idris. These mountains attain an elevation of betwen 3000 and 4000 feet, their summits are jagged and irregular, their declivities steep and barren, and the neighbouring passes and valleys have all the peculiarities that slate confers; among them, the Dell of Aberglaslyn, viewed from the bridge which unites Merionethshire to the country of Caernarvon, presents a grand and awful feature. The rocks are lofty, lonesome, and black; their sides exhibit terrific and inaccessible precipices; or where the slopes are more gentle, they are covered with the sharp angular fragments, which time and the elements have dislodged from above. The wood-cut at the head of this Section shows the character of the clay slate upon the coast of North Wales.

Advancing northwards, the mountain chain is broken by the lowlands of Lancashire; but in Westmoreland and Cumberland slate again presents itself, plentifully accompanied by grauwacke, which contributes to the enchanting scenery of the lakes. As black peaks and preci-

es strewed with slippery and cutting fragments mark the mountains of
ommon slate, so have the grauwacke rocks peculiarities by which they
re recognised, and which are no where more evident than in the
ounded summits that embosom Derwentwater, as represented in the
nnexed cut. In their forms, tints, and outlines, there is something

ndescribably delightful, and they present that rare union of the sub-
ime and beautiful, of which no better idea can be formed, than that
uggested by Mr. Burke's comparison: "Sublime objects are vast in
heir dimensions; beautiful ones comparatively small; beauty should
e smooth and polished; the great, rugged and negligent; beauty
hould shun the right line, yet deviate from it insensibly; the great,
n many cases loves the right line, and when it deviates, it often makes
strong deviation; beauty should not be obscure; the great ought to
e dark and gloomy; beauty should be light and delicate; the great
ught to be solid and even massive." These qualities of that which
sublime, well apply to the rocks I have before described, and, when
lended with the parallel definition of the beautiful, furnish a just notion
f the aspect of those now under consideration.

2094. The varieties of MOUNTAIN LIMESTONE (the TRANSITION LIME-
ONES of the Wernerians) are the substances that next occur. They
e frequently seen immediately incumbent upon clay-slate, and are fur-
er distinguished from primitive limestone, or statuary marble, by hav-
g a less decidedly crystalline texture. Where this rock lies directly
on slate, it contains few organic remains; but where red sandstone is
terposed between it and the slate-rocks, or in proportion as it is distant
om the primary and slate-rocks, the relics of organization become more
equent. It then abounds in remains of corals and zoophytes, which
w are not known to exist. It often is traversed by veins of calcareous
ar, and presents a great variety of colours. It is abundant in Devon-
ire, South Wales, Derbyshire, and Yorkshire. At Plymouth this
ck is seen immediately incumbent upon slate, in a quarry between
e Dock and the Town. Its colours are red and grey, streaked with

white crystalline veins. It is also seen to great perfection in the Breakwater quarries at Oreston.

2095. Slate districts often present very curious inflexions and incurvations of their strata. The slate at Plymouth, and the grauwacke of Clovelly in the north of Devon, and the killas upon the coast of Cornwall near Charlestown, are in many places very singularly contorted; and sometimes small undulations present themselves in the laminæ, exactly resembling those left by the ebbing tide upon a gently reclining sand-bank. These appearances may, perhaps, be referred to the action of water upon the materials before they were consolidated.

2096 Limestone strata are also very remarkable for the inflexions and curvatures, referred, not very satisfactorily, by Dr. Hutton to their having been in a soft state at the time they were disturbed from their horizontal position. There are some very curious instances of these curvatures noticed by Saussure; one, in particular, on the road from Geneva to Chamouny, where the small stream of *Nant D'Arpenaz* forms a cascade by falling over a perpendicular surface of limestone rock; the strata are bent into regular arches, with the concavity to the left; while in another neighbouring mountain they turn to the right; so that a verticle section of the two would present the figure of S. The top of Benlawers in Perthshire, and the coast of Berwickshire, with many other districts in Scotland, present instances of these singular contortions. Dr. Hutton has given a plate of the bent strata in Berwickshire, from a drawing made by Sir James Hall. I cannot here follow Dr. Hutton and his sagacious commentator through their arguments founded upon these phænomena, they attempt to prove that the undulated strata have received their *peculiarities upon* level ground; that they have then been elevated, *hardened, and often* bent and contorted during these processes; and that their *irregularities* as to position, and their fractures and dislocations have thus occured, and do not result, as the opposite school would have it, from the falling in of caverns,—a position which they assume as at once accounting for such appearances, and for the retreat of the ocean. Hutton considers the land to have been raised, Werner supposes the waters to have retreated.

2097. The aspect of a country of mountain limestone is peculiar, and generally extremely picturesque. The hills, which, in this country at least, are not very lofty, abound in precipices, caverns, and chasms; and, when upon the coast, form small promontories, and jut out in low but grotesque pillars. The even surfaces are covered with a stinted turf, but the rifts and cracks contain often a soft rich soil in which stately timber trees flourish. The chasms of limestone rocks are often filled with a fine clay, which has, perhaps, sometimes been derived from the decomposition of shaly strata, or sometimes deposited from other causes in the fissures, and the singularities of aspect, and much of the beauty of this rock, is referable to these peculiarities. Thus, upon the banks of the Wye, large and luxuriant trees grace the abrupt precipices, and jut forth from what appears a solid rock. Their roots are firmly attached in some crevice filled with a favourable soil. Sometimes rivers force their way through the chasms; at other times they are empty, and the roofs ornamented by nature's hand with stalactitical concretions of white and glistening spar, which seem like the fretted sculpture of Gothic architecture.

The views of Dovedale, and of Matlock and its vicinity; and the caves of Castleton, are admirably illustrative of the scenery of mountain limestone. Pont-Neath Vaughn, in Glamorganshire, is full of its beauties; and the panorama of Swansea Bay, seen from the Mumbles Point, furnishes a pleasing, characteristic, and perhaps unrivalled, prospect of these rocks.

The banks of the Avon too, in the vicinity of Chepstow, are of mountain limestone. The rock is there impregnated with bitumen, and hence exhales a peculiar and fetid odour when submitted to the blows of the axe or hammer. This is by no means uncommonly the case where the limestone rock, as in the present instance, is in the vicinity of coal. The following sketch may serve to give some idea of the appearance of the mountain limestone of Dovedale, in Derbyshire.

2098. Mountain limestone is an excellent material for building, and many of its varieties are sufficiently indurated to receive a good polish, and are thus employed for ornamental purposes, being cut into vases, chimney-pieces, and the like. Where they abound in corals, and other organic remains, these frequently add to their beauty.

The colours of transition limestone are various, but its essential constituent part is always carbonate of lime. The black variety known under the name of *Lucullite**, or black marble, has long been admired, and is often tastefully manufactured and ornamented by etching upon its surface. It is found in Derbyshire, Sutherlandshire, and Galloway, and appears to derive its colour from carbonaceous matter.

All these limestones are converted into a more or less pure *quick lime* by the operation of a red heat, and are thus often valuable as affording manures, and for other purposes.

2099. The next rock that occurs in point of succession, is RED SANDSTONE. It often rests upon slate, and then, from its position has acquired the term of *old red sandstone*. But a similar substance, or nearly so, also is found lying upon mountain limestone, in which case it has been called *red marl*, or *new red sandstone*.

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* A name given to the marble in consequence of the admiration bestowed upon it by Lucius Lucullus. Vide *Plinii Hist. Nat.*, 36. 8.

Entering upon this substance, we come upon distinctly stratified ground; it is very abundant in England, especially in Lancashire, Cheshire, Staffordshire, Shropshire, and Worcestershire; and independent of its embowelled treasures, for it is connected with coal and rock salt, its surface is generally favourable to vegetation, and its soil sufficiently luxuriant. It consists principally of siliceous particles, and oxide of iron, with some argillaceous earth, and more or less calcareous matter. Its beds are often of great thickness, as may be seen in the quarries; it is much used as a building stone, but moulders in consequence of the action of air and moisture upon the oxide of iron. It often contains particles of mica, and fragments and pebbles of old rocks.

3000. Red sandstone rocks are seen in some parts of Britain in great beauty and perfection, especially where they occur on the coast, or are intersected by rivers. At Ilfracomb, the old red sandstone of the Somersetshire coast is seen lying upon slate; and the junction is interesting to the geologist, the sandstone becoming somewhat slaty, and the slate having a tendency to a granular fracture. The following sketch of Hawthornden, near Edinburgh, shows the characteristic features of the red marl rock, or newer red sandstone; and the ancient castle, with its dungeons and vaults, is constructed of this material. Ridges of red sandstone, containing mica and fragments, sometimes accompany primary rocks, of which a very singular instance occurs upon the banks of Loch-Beauly, near Inverness; a high range of granite is there bordered by a breccia, very like that of the bed of the Fyers; and a low ridge of red sandstone, of which the valley is also composed, accompanies the series, and seems the detritus of the more ancient and lofty formations.

3001. The slates, grauwackes, and limestones, are in this country the principal seats of the metallic ores; and they form scenery which gradually decreasing in grandeur and sublimity, increases in softness, variety, and luxuriance. In the lowest sandstone formation, we meet with a variety of bodies of the utmost importance in our arts and manufactures.

3002. A substance which occurs in abundance in many parts of the red strata, is *gypsum* or *sulphate of lime*, known also under the name of *plaster-stone*, *selenite*, and *alabaster*. Near Tutbury in Staffordshire, and near Nottingham, it is found in blocks and veins; and lately a variety, new in England, has been found, called *Anhydrite*. These minerals constitute valuable materials for the ornamental manufactures of Derbyshire.

3003. In the county of Cheshire the red sandstone contains immense beds of *common salt*, most abundant in the valley of the Weaver, and near Middlewich, Northwich, and Nantwich; it is accompanied by gypsum. The first stratum was discovered about 150 years ago, in searching for coal. It begins about 30 yards from the surface, and is 25 yards thick; below this, and separated from it by 10 or 12 yards of indurated clay, is another bed of salt, the extent of which is unknown; in many places it is nearly pure, in others tinged with oxide of iron and clay. This pit is at Northwich; and at other places there are very abundant brine springs. A most remarkable circumstance in the Northwich mine is the arrangment of the salt, giving rise to an appearance something like a mosaic roof and pavement, where it has been horizontally cut. The salt is compact, but it is arranged in rounded masses, five or six feet in diameter, not truly spherical, but each compressed by those that surround it, so as to have the shape of an irregular polyëdron. The Wernerians regard the salt as having merely crystallized here from its aqueous solutions; the Huttonians consider the water to have been evaporated by heat. The large pit at Northwich presents a very singular spectacle when duly illuminated; it is a circle of nearly two miles in circumference, the roof is supported by massive pillars of salt, and the effect is heightened by the variety of colours it presents*.

3004. *Coal* is the most important product of these middle strata. What is called a *coal field*, or *district*, or sometimes a *coal basin*, may be regarded as a concavity, varying greatly in extent, from a few to many miles, and containing numerous strata or seams of coal of very various thickness, alternating with sandstone, clays, and soft slate or *shale* containing impressions of vegetables and sometimes the remains of fresh water shell-fish. The parallelism of these strata is generally well preserved. The whole arrangement is seldom any where quite horizontal, and never vertical, but almost always more or less inclined. Beneath each stratum of coal, there is often one of soft clay, or *clunch*, which rarely contains the organic remains of the overlying shale: and although the alternating strata of coal be very numerous, it is seldom that more than three or four will afford profitable occupation to the miner. The upper seam is commonly broken and impure, and few beds, less than two or three feet in thickness, are followed down to any conconsiderable depth. The depth of the mines will of course greatly vary, according to the inclination of the strata, the time they have been worked, and other circumstances. Our deepest mines are in the counties of Durham and Northumberland, and the thickest beds are found in Staffordshire. The most productive vary from six to nine feet.

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* See *A Sketch of the Natural History of the Cheshire Rock-salt District.* By Henry Holland, Esq.—*Geol. Trans.* i. 38.

3005. There are several varieties of coal, but, as far as their economical applications are concerned, they may principally be reduced to two. The coals of Lancashire, Scotland, and most of those raised upon the west of England, burn quickly and brilliantly into a light ash: while the coal of Northumberland and Durham, becomes soft and puffy, spouts out bright jets of flame, requires poking to continue in combustion, and produces bulky cinders, which, if urged in a violent fire or mixed with fresh coals, run into slags and clinkers.

3006. Though coal is chiefly found in the geological position I have mentioned, constituting the *independent coal formation* of Werner, it is likewise found in other situations, amongst newer rocks, and sparingly in alluvial soils. But in this country, the main coal formations are marked by their position; their contiguity to limestone and often to slate; by micaceous grits and sandstones; and, above all, by shale with vegetable impressions, decomposing into tenacious blue clay.

3007. The greater number of geologists are now unanimous as to the vegetable origin of coal; and, indeed, its composition, the abundance of vegetable bodies with which it is often associated, and the gradual transitions of wood into coal, discoverable in many parts of the world, may be considered as satisfactory evidence upon this subject: but how it has been formed, is another and more intricate question.

Dr. Hutton considered coal strata to have been produced by the operation of subterranean heat, in the manner already described, acting upon vegetable bodies and charcoal under exceeding pressure, which prevented the usual phænomena of combustion, and hindered the escape of the inflammable part. Sometimes, he observes, more or less bitumen has been driven off, for we find it in other strata.

By Mr. Williams, antediluvian timber and peat bog are regarded as the source of our present coal; and a variety of curious circumstances, which the minute history of coal fields presents, have been adduced as favourable to his conclusions.

3008. The coal miner is often seriously interrupted in his proceedings, by large fissures or breaks in the strata, and by veins of a hard black rock, which cut through the coal, sometimes merely dividing it, at others throwing it out of its former position. It is in the neighbourhood of these *dykes* and *troubles*, as they are called by the miners, that immense quantities of carburetted hydrogen gas are frequently evolved, though the coals themselves, and the cavities in the strata, also yield it; it constitutes the *fire-damp* of the mines; and when it has any where collected so as to constitute more than $\frac{1}{15}$ of the volume of atmosphere, it becomes explosive whenever a flame is presented to it, and the source of such dreadful destruction, that the mind recoils from the recital. Formerly the miners, in these dangerous situations, availed themselves of the light obtained by the collision of flint and steel, which, however, was by no means free from danger, and has been completely superseded by Sir Humphry Davy's safety lamp.

3009. Another substance which very often attends coal formations, is *argillaceous iron-stone*, both in layers and nodules; and although a poor ore of iron, very seldom yielding more than 30 *per cent.* of metal, it becomes, from its association with coal and limestone (substances required for its reduction), a most important natural product; it is the main source of the enormous quantities of iron manufactured in this country; and the history of the various difficulties which have been surmounted in completing the processes of its reduction, presents an unrivalled picture of skill, ingenuity, and perseverance (725).

3010. Leaving the districts of red sandstone and red marl, we observe a change in the general aspect of the country. There are no steep or abrupt precipices: the hills assume a more picturesque and luxuriant character, and the rugged features of primary country, are here softened down into gentle slopes and verdant plains.

The rocks which now occur are chiefly varieties of limestone and sandstone, particularly prolific in organic remains; among them we discern a number of species of which no living semblance is now in existence.

Corals, zoophytes, ammonites, belemnites, nautili, and a variety of other fossil remains, are found in the ARGILLACEOUS LIMESTONES, which succeed in position to the red sandstone, and which are often called *white* and *blue lias limestone.* The coast of Dorsetshire, between Weymouth and Lyme, presents a very interesting section of these strata; and their continuation through the country is well entitled to the notice of the geologist. They decompose into marl, and furnish an ingredient in the best water-cements. Sometimes they are of a peculiar yellow colour, and contain magnesia, when the fossil remains are less frequent.

3011. These strata are succeeded by a species of stone, often called *Bath-stone*, from its abundant occurrence in the vicinity of that city, and *freestone*, or OOLITE, of which *Portland-stone* is a notorious variety. There then commonly occur various SANDSTONES, with veins of chert and oxide of iron; and, lastly, we arrive at CHALK, and superincumbent ALLUVIAL MATTER.

3012. The examination of the fossil remains in these strata, leads to conclusions of much interest and importance. In the strata upon the coast of Dorsetshire, below the chalk, we find the remains of an animal, which has generally been regarded as a crocodile, or allegator*, but there are no fossil relics of mammiferous land animals, either here, or in the chalk itself; whence it has been concluded, that oviparous quadrupeds are of more ancient date than those of the viviparous class, and that dry land and fresh water existed before the formation of our present chalk. In the vicinity of Paris the chalk is covered by a coarse shell limestone, in which the bones of mammiferous sea animals have been found by Cuvier; but no bones of mammiferous land quadrupeds occur, till we reach the more recent and superincumbent strata.

3013. The *chalk* presents the geologist with much matter of speculation. In England it is a very abundant formation, and the round-backed hills covered with verdure which mark the eastern counties, are very characteristic of it. Salisbury Plain and Marlborough Downs form a centre, whence the chalk emanates, in a north-eastern direction, through the counties of Buckingham, Bedford, and Cambridge, and terminates on the Norfolk coast. In an easterly direction it traverses

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* Sir Everard Home, in examining the fossil bones of this animal, has thrown considerable doubt upon the above conclusion; and, from a peculiarity in the structure of its spine, resembling that of the *proteus*, has called it *proteorrhachius.*

Hampshire, Surry, and Kent, and terminates at Dover; and another arm passing through Sussex, east south-east, forms the South Downs, and the lofty promontory of Beachy Head. Parallel ridges of sandstone generally accompany the chalk, and in Wiltshire, Berkshire, and some other counties, large blocks of granular siliceous sandstone lie scattered upon its surface; of these the celebrated druidical relics, called *Stonehenge*, appear to have been constructed, with the exception of one of the blocks, which is of greenstone. The lower beds of chalk are generally argillaceous, or marly, and contain no flints, and few organic remains. The upper beds abound in fossil relics, of the kinds before alluded to, and in flints sometimes regularly arranged in distinct nodules, at other times remarkably intersecting the chalk in thin seams. The formation of flint has been much speculated upon, but no plausible theory has yet been adduced in regard to it.

3014. In the south of England the chalk is covered with gravel and clay, the history of which is extremely curious, on account of the fossils which they contain, and the evidence they afford of repeated inundations of salt and fresh water upon the same spot. There are two celebrated concavities filled with such materials which have been called the London and the Isle of Wight Basins. The former is bounded by the chalk-hills proceeding from Wiltshire to the south of the Kentish coast, in one direction, and to the northern point of the Norfolk coast in another; and it is open to the ocean upon the Essex, Suffolk, and Norfolk coasts, which show sections of its contents.

The numerous wells which have been dug in the neighbourhood of London, and the canals, tunnels, and other excavations and public works which have been carried on, have lately made us acquainted with many curious facts respecting the contents of this basin.

It deserves remark, that all the bones of viviparous land quadrupeds have either been found in the uppermost fresh water deposits, or in those alluvial formations of the ocean, which appear to have been the result of violent transportations of materials, rather than of quiet depositions; so that it is probable these animals began to exist during that state of the world which preceded the last inundation of the sea.

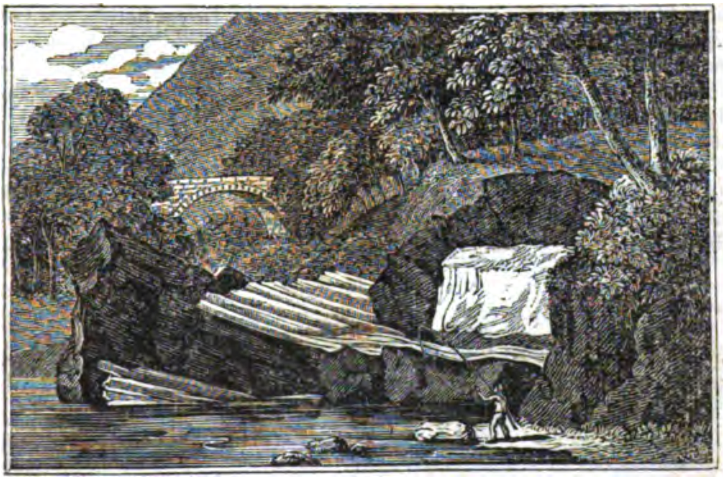
The *palæotheria*, *anaplotheria*, and other unknown genera described by Cuvier, are found in the lowest parts of the upper fresh-water formation, placed immediately under the upper marine formation. Some oviparous quadrupeds and fresh-water fish are found along with them, and they are covered by alluvial deposits, containing marine relics.

The unknown or extinct species belonging to known genera, such as the *mastodon*, *elephant*, *hippopotamus* and *rhinoceros*, are never associated with the more ancient or extinct genera, but are discovered usually in the sea-water deposits; and the bones of species resembling those that now exist, are found upon the sides of rivers, or in the bottoms of ancient lakes and marshes, or in peat-bogs, or in caverns and fissures of rocks; and, in consequence of their superficial situation, they are generally much injured.

3015. Of a very singular and important series of rocks, I have yet made no mention. They occur indiscriminately in primary and secondary countries, and are not less varied in their characters and aspects, than in their situation. These are the *trap-rocks* of the Wernerians, and the *whinstones* of Dr. Hutton. They include the rocks called GREENSTONE, BASALT, AMYGDALOID, and TOADSTONE, and are distinguished into primary, transition, and floetz traps, by the school of Freyburgh.

By the term *greenstone*, we mean a compound of hornblende and feldspar, differing extremely in its appearance, being sometimes so fine grained as to appear homogeneous; at other times presenting distinct, and often large, crystals of hornblende. *Basalt* is always a homogeneous rock, and abounds in black oxide of iron. Its cavities are often filled with calcareous spar, zeolite, and agate nodules.

Greenstone is met with in many parts of England immediately upon granite and primary rocks; and it assumes the character of its neighbours, breaking into large blocks and masses of very irregular appearance. In this state it is seen in Cornwall, at the Lizard-Point. Upon the north side of the Welsh mountains, a chain of greenstone follows the slate, which, in some places, is columnar, as upon Cader Idris, and it forms a singular concavity near the summit of that mountain, very like the crater of a volcano. In Derbyshire these rocks are among the transition series of Werner. They form strata, and fill cavities in the limestone. In coal-fields they constitute dykes, or veins; and, among the newest and secondary strata, they are seen in sandstone at Edinburgh, and upon the coast of Antrim they are incumbent upon, and alternate with, chalk. The annexed wood-cut, taken from a sketch by Dr. Mac Culloch, engraved in the *Geological Transactions*, Vol. iii., represents a remarkable dislocation occurring at Gow's Bridge, in Glentilt, in Scotland, of the schistose strata by the black mass of hornblende rock, which also contains an embedded mass of marble.



3016. The common observer, to whom a piece of basalt is presented, would presently announce it to be the produce of a volcano, and the analogy between it and lava is most striking. This alone would justify us in concluding, that whinstone is the produce of fire. But the Huttonian hypothesis, as applied to its origin, becomes much more satisfactory, when we contemplate the effects produced upon the strata into which it has been thrown, or upon the substances in its vicinity. Thus the sandstone of Salisbury Craigs, near Edinburgh, is broken, indurated, and even apparently fused by its irruption. The soft white limestone of the county of Antrim, where in contact with the basaltic dyke, is hardened and rendered crystalline, like marble and calcareous spar; and the coal in the same county is coaked, as it were, where touched by the whinstone. At the same time, the dykes themselves bear evident marks of igneous fusion. They are more regularly crystallized in the centre than upon the surface, an effect which may be well referred to the different rates of cooling, in the melted mass, and which may even be imitated artificially with the slag of an iron furnace.

Perhaps the most remarkable phænomenon concerning basalt, is its occasional columnar structure, an appearance which lava sometimes assumes. Upon this subject Sir James Hall's experiments are of extreme interest; and, when conjoined with those of Mr. Watt, produce a further, and, indeed, almost irresistible evidence in favour *of the igneous* origin of basalt.

3017 In accounting for the humid origin of basalt, the Neptunists refer to the columnar cracking of clay, mud, starch, *&c.*, during drying; and in this they fancy an analogy to basaltic columns; but in these cases, there are always chasms and vacuities produced by the shrinking of the mass; whereas the columns of basalt are so closely connected, that the thin blade of a knife can scarcely be thrust between them. Upon the whole, the Huttonian theory may be considered as no where more free from objections, than where it applies to basalt; while the hardening, contortions, and breaking of the strata by whin dykes, and the numerous analogies of basalt and lava, are to the *Neptunians* paradoxes which admit of no solution.

3018. Of columnar basalt, the British dominions present *the noblest* specimens in the known world. Upon the coast of Antrim, in Ireland, massive and columnar basalt is seen in all its varieties, the former abounding in deep and lofty caverns, the latter presenting various fa-

cades to the ocean. The Giant's Causeway, a small part of which, with the neighbouring coast, is shown in the above wood-cut, consists of three piers of columns, which extend some hundred feet into the sea. It is surrounded by precipitous rocks, from two hundred to four hundred feet high, in which there are several striking assemblages of columns, some vertical, some bent or inclined, and some horizontal, and, as it were, driven into the rock. Bengore, which bounds the Causeway on the east, consists of alternate ranges of tabular and massive, with columnar basalt. But amongst the various and grand objects on this coast, Pleskin is perhaps the most striking; it presents several colonnades of great height and regularity, separated from each other by tabular basalt; and at Fairhead there is a range of columns of from 10 to 20 feet in diameter, and between 200 and 300 feet high, supported upon a steep declivity, and forming a terrace which towers nearly 600 feet above the waves beneath. He who would really see the sublime should visit this stupendous promontory.

Another basaltic district, which I am inclined to regard as exceeding the former in magnificent peculiarities, is that which presents itself in sailing down Loch-Nagaul, in Mull, towards the Isle of Tiree. The coast of Mull, upon the right and left, exhibits the step-like appearance of basaltic rocks in great perfection, and has fine caverns and columns; the islands of Ulva and Gometra rise with the abrupt and irregular precipices common to this formation. The Treshamish Isles exhibit columnar and massive basalt, and in the midst of this curious panorama, Staffa presents itself. The columns, which are from 30 to 50 feet high*, are approached by a fine causeway, rising gradually from the deep, and they appear to support an immense weight of tabular basalt. The pillars are perpendicular, inclined, and in places extremely curved; and in the Cave of Fingal the ranges of columns extend in long perspective into the interior of the rock, presenting a scene of such unrivalled grandeur, as hitherto to have foiled all attempts of the poet to describe, or of the painter to represent. The wood-cut at the head of the next Section, copied from Dr. Mac Culloch's sketch, represents the Causeway and entrance of the Cave.

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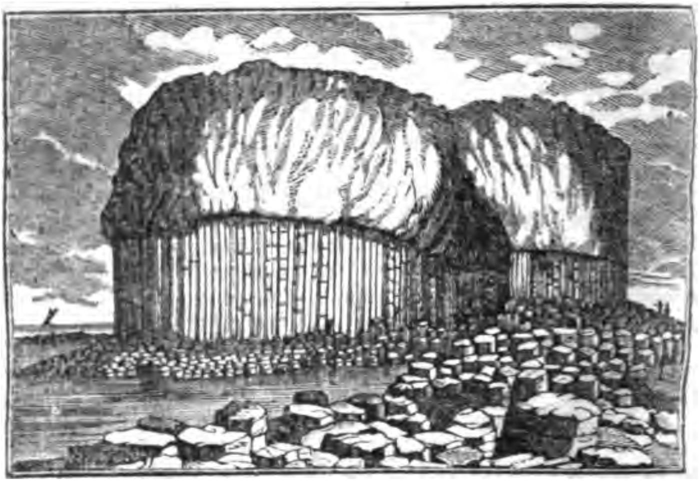
* See Dr. MAC CULLOCH'S *Description of the Western Islands of Scotland*, Vol. ii. p. 1.



SECTION IV. *Of Metallic Veins.—Of the General Causes of the Decomposition of Rocks.—Of Volcanoes: and of the Analysis of Soils.*

3019. BESIDES the veins of lapideous substances, the fissures filled with debris and rubbish, the dykes, the beds of salt, and the fields of coal, there are diffused through the strata a variety of other treasures, among which the metals are of the utmost interest and importance. By the term *Mineral Vein*, we mean a separation in the continuity of a rock of determinate width, but extending indefinitely in length and depth, filled with metallic ores, and crystalline substances, differing from the rock itself.

Nearly all rocks are occasionally thus traversed, but the middle series are those in which metals are most abundant. In Cornwall, for instance, tin occurs both in the granite and slate; but it is most abundant in the latter, and the vein occasionally runs between the two rocks, so that one wall consists of granite, and the other of slate. The metal is often separated from the rock by thin layers of clay, or of stony materials, called *Deads*, which also intermix with the ore, and form its *gangue* or *matrix*.

3020. The richest metallic veins run, without exception, east and west. Those which run north and south being usually filled with stony materials. The latter veins appear of posterior date to the former, for they often intersect them throwing them out of their regular course; generally a few inches only east and west, but many fathoms north and south. These *cross courses* often interfere with the treasures of the metallic vein, though, when solid, they are sometimes of great service in keeping out water.

3021. The extent to which veins may be pursued, is extremely various, and depends much upon accidental circumstances. Sometimes a cross course cuts the vein, and puts an end to the miner's hopes, he being unable to discover its continuation after such interruption; sometimes the depth of the vein becomes so great, that it cannot be prudently pursued; sometimes a rich lode of metal suddenly disappears, or vanishes into thin strings, which, though often quite lost, occasionally reunite into a good vein, or bunch of metal. So that, taking all these circumstances into account, between two or three miles is usually the utmost extent to which a vein has been pursued*.

3022. Veins vary in width, from an inch or two, to 30 or 40 feet, but the middle-sized veins are usually most prolific, the larger becoming relatively poor. The influx of water was formerly an insuperable impediment to the pursuit of a vein, and remains now a serious and expensive obstacle to mining. Formerly many veins in Cornwall were only worked for tin, which, at greater depths, have lately yielded abundance of copper; but in Cornwall copper is never found without water, and all the mines of that metal require drainage by engines, or other means.

3023. Concerning the original formation of metallic veins, there has been considerable collision of sentiment among geologists; but two circumstances seem sufficiently obvious; one, that they are of later date than the containing strata, that they are not contemporaneous; and the other, that their contents have been in a fluid state. The former position is indicated by their intersecting different strata; the latter, by the crystalline forms of the substances they contain. The Neptunians tell us that veins have been filled by metallic and lapideous solutions flowing in from above, but they do not inform us of the nature of the solvent which held the different bodies they present; nor can we guess why its contents are deposited exclusively in the vein, and not found upon the adjacent surface.

3024. The Plutonists consider veins as filled from below, by the injection of matters in igneous fusion; and in the shifting, breaking, and dislodgement of the strata, they read the force with which these operations have been performed. The validity of hypotheses is only to be estimated by their accordance with facts; and although there be many inexplicable phænomena attending metallic veins, yet the nature of their contents is such as to favour the igneous hypothesis, and to lead to the belief that fire, not water, has been the grand solvent of which nature has here availed herself. That the metals have passed from the fluid to the solid state, seems sufficiently obvious, from their crystalline form; and it is much more probable that they should have been liquefied by heat than by any other solvent.

Sulphur is very commonly found united to metallic bodies, and the greater number of metallic ores contain that element. Such compounds are easily produced by the artificial agency of fire, but with great difficulty by any other process.

3025. A very curious fact in the history of veins is, that they are of different dates, for one vein often intersects another, and we are thus enabled to judge of their relative ages. In the county of Cornwall, one of the richest mining districts of the world, we observe some remarkable circumstances of this kind. Where a copper and a tin vein, for instance meet, the former always cuts through the latter, and generally throws it out of its old course, greatly to the distress of the miner, who sometimes cannot find its continuation, or at least is put to much difficulty and expense to do so. It appears, therefore, that tin veins are invariably older than those of copper. Sometimes, as in Derbyshire, the metallic ores lie in large longitudinal cavities, called *pipe veins*.

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* See a valuable paper on the *Veins of Cornwall*, by Mr. W. Phillips. *Geol. Trans.* Vol. ii., and also annexed to his *Selection of Facts*.

3026. In searching for veins of the useful metals, there are certain indications of which the experienced miner sometimes profitably avails himself. Thus, a green earthy matter is a good symptom in a tin mine; a brown ochrey earth, and compact iron pyrites, are regarded as favourable omens in a copper mine.

Detached pebbles of ore, or fragments of vein-stones, have sometimes led to the riches of the vein, and tin has especially been thus discovered in Cornwall.

In older mineralogical works we read much upon these and other subjects. Flames of light have been described as playing over a district which afterwards has been found to contain subterranean riches, and this may have arisen from the good electrical conducting powers of the vein. The waters issuing from the soil sometimes hold metallic salts in solution, and repositories of the metals have been discovered by circumstances of this kind. Copper veins tinge waters blue, and a piece of grease put into them becomes rapidly stained of that colour.

There is no popular notion more common than that metals grow in the veins: an idea which may very probably have originated from observing the depositions of one metal by the introduction of another into its solution, as when silver is precipitated by the introduction of a plate of copper into its solution, or copper by iron.

3027. Districts rich in the metals are generally barren, and seem peculiarly dreary and desolate to the traveller. This partly arises from the nature of the strata; partly from the heaps of rubbish and hills of stone thrown upon the surface: and partly from the operations carrying on in the vicinity, being inimical to vegetation. The high road through Cornwall, especially near Redruth, is an excellent specimen of this kind of country; while, at the same time, the romantic beauty and luxuriant vegetation of many parts of that county, and of Devonshire, prove that exterior cultivation is not always incompatible with internal riches. The neighbourhood of the Parys Mountain, in Anglesea, is singularly marked by sterility and gloominess. The soil, naturally unproductive, is rendered more so by the poisonous waters that traverse it, and the sulphurous vapours that float around. There are not only no shrubs and trees, but the barrenness is unrelieved even by a single blade of grass, or the rusty green of a hardy lichen.

3028. I have hinted above at the relative permanence and durability of the different kinds of rocks, and it has been found that the unstratified, or primary, substances, are least acted upon by the elements; that these have retained their great and pristine elevation, while the secondary strata have been washed from their sides and summits, whose rugged and abrupt outline records this devastation. Every one who views the mountain side strewed with immense blocks of materials transported from distant summits, and discovers the dells and valleys filled with fragments and pebbles of the neighbouring rocks, will allow that a constant system of disintegration and decay is here carrying on; but the geologist, not content with the mere observance of the fact, will endeavour to trace it to its source, and follow it up to its ultimate effect.

3029. The change of temperature to which the earth's surface is constantly submitted, is one great cause of the slow destruction of its most solid and durable constituents; and when to this is added the gigantic power with which water, in becoming ice, opposes the obstacles to its expansion, we have an agent nearly resistless. The fissures that occur between the blocks and masses of the granites, porphyries, and similar rocks, become filled with water, which, in the act of freezing, expands so as slowly to remove them from each other; their edges and angles become thus open to the attacks of the weather, and by a slow dislodgement they fall into the valleys or rivers, or are at once cast into the ocean. Where the materials are of a more yielding and frangible texture, this destruction is proportionally rapid, and the influence of the weather upon slate mountains, is often such as to produce hills of fragments at their feet: the softer substance of the secondary and horizontal strata is, of course, yet more easily and quickly degraded.

3030. Masses of rock, thus loosened from their original beds, become new and powerful instruments of destruction; they roll down the precipices, wearing themselves and the surface that bears them, and, if near the sea, or carried thither by rivers, they become "a part of the mighty artillery with which the ocean assails the bulwarks of the land;" they are impelled against the coasts, from which they break off other fragments: and the whole thus ground against each other, whatever be their hardness, are reduced to gravel; the smooth surface and rounded masses of which are convincing proofs of the manner in which it was formed.

3031. It is by operations of this kind, not performed in a day, but in ages, that nature has indented and carved out the earth's surface; that the rivers seem to have cut their own beds; that the land is undergoing gradual demolition; and that the materials which we have elsewhere considered as consolidated at, and elevated from, the bottom of the ocean, are gradually restoring to the parent deep. These are mechanical agents, but they are not unassisted by the chemical energies of matter; and, in this respect, the solvent powers of water may be contemplated as effecting most important changes.—KIDD's *Essay*, p. 181.

3032. By impregnation with carbonic acid, water acquires a great solvent power over carbonate of lime (642,) and in trickling through, such strata becomes saturated with it, and, on exposure, again deposits it, in consequence of the escape of the gaseous solvent; it is thus that the stalactitical concretions of limestone caverns are produced, as in the Fluor Mine, and Peak Cavern of Derbyshire; and, in many cases, the once empty chasms are entirely choaked up by this sparry deposit. The power of incrustation, thus possessed by some waters, is such as rapidly to cover extraneous bodies thrown into them with a calcareous coating, of which the petrifying spring of Matlock furnishes a good example.

3033. The sands upon flat coasts are sometimes agglutinated by this action of water, so as to produce a new rock; or, as the Wernerians would call it, a new formation. This has probably been the case with the stone in which the *galibi*, or human skeletons of Guadaloupe, are found (*Phil. Trans.* 1816,) and the process is constantly going on upon the coast of Cornwall, in the parish of St. Columb, where the water, having percolated the neighbouring rocks, becomes slightly carbonated and ferruginous, and thus serving as a cement to the sand, produces a hard stone, which is used as a building material, and for making cattle-troughs. In the walls of some of the oldest churches in Cornwall, as in St. Burian, Gwithian, Crantock, Cubert, &c., are large masses of this *sandstone*, which has thus long resisted decomposition. When water is hot, and slightly alcaline, it dissolves siliceous earth, as shown by the deposits of the Geysers, or Boiling Fountains of Iceland.

3034. Some rocks suffer, in consequence of the action of air and water upon the black oxide of iron which they contain, and which, in passing into the state of brown oxide, occasions a crumbling of the mass. Much of the soil upon the coast of the county of Antrim, in Ireland, is thus derived from the decomposition of basalt, which, however, in other cases, singularly resists change, as in Staffa, where the columns, though exposed to the violence of the ocean, retain a sharp angularity and black colour. These differences depend upon the degree of induration of the basalt.

3035. Rocks containing alcali seem often to decompose rapidly, in consequence of the loss of that ingredient. The quick disintegration of much of the Cornish granite is well known, and it furnishes a valuable material for the manufacture of pottery. The feldspar of this granite contains a considerable portion of potassa, but the white earth into which it is resolved yields no traces of it.

3036. The chemical agencies of different bodies presented to each other in the strata, are also often connected with the production of entire new substances. Thus the decomposition of pyrites in chalk produces sulphate of lime; in aluminous slate it gives rise to the production of alum; and in the cliffs at Newhaven, on the Sussex coast, a very curious series of changes is going on. A stratum of marl, containing decomposing pyrites, lies upon the chalk, which gives rise to the formation of sulphate of alumina; this is decomposed by the chalk; and aluminous earth, selenite, and oxide of iron, are the results.

3037. Thus, by mechanical operations and chemical changes, sometimes separate and sometimes united, the rugged peaks and abrupt precipices are gradually wearing and softening down, and giving rise to rounded summits, gentle slopes, and habitable surfaces. The detritus so produced is carried by rills, and brooks, and rivers towards the low lands, where it is deposited; or it is transported towards the sea, where it forms bars and islands at the mouths of rivers; or it is employed in levelling uneven surfaces, and filling cavities and basins, as where the rivers are broken in their course by the intervention of lakes, all of which are filling up, as may be learned even by hasty inspection. This is no where more conspicuous than in the waters which adorn the scenery of Westmoreland and Cumberland, especially Derwent Water, at the Borrowdale extremity of which the meadow is annually increasing, and adding to the circumjacent field; and the examination of the bank between Derwent and Bassenthwaite, shows that the two lakes were once united, and that the present separation is alluvial matter, or a bar thrown up by the concurrent streams of Newland's Water, on the west, and the Greta on the east. The filling up of lakes, until they ultimately become merely a part of the river that now traverses, but once fed them, is too obvious to require further illustration; it is the reason why the stream, which has its exit from a lake, is generally clear, while the torrents which supply it are loaded with matters in minute mechanical division.

3038. While the destructive agencies of the elements are thus called into action for the production and increase of habitable surface, we observe other causes tending to the same effect, and none more wonderful than the incessant labours of those insect tribes which collect and accumulate solid matter from the ocean, and form the rocks of coral common in the seas of warm climates.—KIDD's *Essay*, p. 219.

3039. But the most striking sources of decay and reproduction, are those dependent upon volcanic phænomena.

The form of volcanic hills is usually conical, of which the outline of the Bay of Naples presents a fine panorama. One of its hills serves to give some idea of the vast powers of the subterranean agents; it is about 1000 feet high, and three miles in circumference, and was raised, in 1238, in a single night*.

3040. In June 1811, a volcano was discovered in the sea off St. Michael, and it formed an island about a mile in circumference.—*Phil. Trans.*, 1812.

3041. To describe the phænomena of volcanic eruptions with all attending circumstances, would be foreign to our present purpose; but as the same causes may have been active in producing other geological phænomena, it becomes right to mention the subject.

Until lately, the cause of volcanic fire was referred to sulphur, coal, and other common inflammable matters, which were supposed to be burning in immense masses within the earth, and thus to give rise to the tremendous explosions and ejections of lava and stones attending the eruption; but the products ill accord with such an explanation. Earthy, alcaline, metallic, and stony bodies united, form the lava; and steam and hydrogen gas accompany its throwing forth; and as the products of combustion always have a reference to the combustible, such matters were not likely to be produced from sulphur or coal.

The discoveries of Sir H. Davy have enlightened this, as well as every other branch of chemistry, and from them we may deduce a very adequate solution of the problem of volcanoes, for we have only to suppose the access of water to large masses of those peculiar metals which constitute the alcaline and earthy bases, and we are possessed of all that is wanted to produce the tremendous effects of earthquakes and volcanoes; for what power can resist the expansive force of steam, and the sudden evolution of gaseous fluids, accompanied by torrents of the earths in igneous fusion, which such a concurrence of circumstances would give rise to, and which are the actual concomitants of volcanic eruptions?

From the same source the Huttonian theory derives great additional plausibility, for its feeble parts were those which related to the required expansive forces, to the intense continuance of heat, to its occasional increase and decrease, and to the existence of a species of fuel adequate to the various effects that have been described. The metals of the earths are equal to the production of all these complicated and apparently incompatible effects, and these and water are the sole agents required.

3042. The principal circumstances that tend to the formation of soils, and to modify their composition, have been adverted to in this

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* See Sir Wm. Hamilton's Paper in the *Phil. Trans.* for 1771.

Chapter; and, from the properties of their component parts, elsewhere detailed, the means of analyzing them are to be deduced; but as this is a subject upon which the agriculturist may sometimes find it expedient to employ himself, I insert the following popular instructions upon it, from Sir H. DAVY's *Elements of Agricultural Chemistry*:

"In cases when the general nature of the soil of a field is to be ascertained, specimens of it should be taken from different places, two or three inches below the surface, and examined as to the similarity of their properties. It sometimes happens, that upon plains the whole of the upper stratum of the land is of the same kind, and, in this case, one analysis will be sufficient; but in valleys, and near the beds of rivers, there are very great differences; and it now and then occurs that one part of a field is calcareous, and another part siliceous; and in this case, and in analogous cases, the portions different from each other should be separately submitted to experiment.

"Soils, when collected, if they cannot be immediately examined, should be preserved in phials quite filled with them, and closed with ground-glass stoppers.

"The quantity of soil most convenient for a perfect analysis, is from 200 to 400 grains. It should be collected in dry weather, and exposed to the atmosphere till it becomes dry to the touch.

"The specific gravity of a soil, or the relation of its weight to that of water, may be ascertained by introducing into a phial which will contain a known quantity of water, equal volumes of water and of soil, and this may be easily done by pouring in water till it is *half full*, and then adding the soil till the fluid rises to the mouth; the *difference* between the weight of the soil and that of the water *will give the* result. Thus, if the bottle contains 400 grains of water, and *gains 200 grains* when half filled with water and half with soil, the specific gravity of the soil will be 2, that is, it will be twice as heavy as water; and if it gained 165 grains, its specific gravity would be 1.825, water being 1.000.

"It is of importance that the specific gravity of a soil should be known, as it affords an indication of the quantity of animal and vegetable matter it contains; these substances being always most abundant in the lighter soils.

"The other physical properties of soils should likewise be examined before the analysis is made, as they denote, to a certain extent, their composition, and serve as guides in directing the experiments. Thus, siliceous soils are generally rough to the touch, and scratch glass when rubbed upon it: ferruginous soils are of a red or yellow colour; and calcareous soils are soft.

"1. Soils, though as dry as they can be made by continued exposure to air, in all cases still contain a considerable quantity of water, which adheres with great obstinacy to the earths and animal and vegetable matter, and can only be driven off from them by a considerable degree of heat. The first process of analysis is, to free the given weight of soil from as much of this water as possible, without, in other respects, affecting its composition; and this may be done by heating it for ten or twelve minutes over an Argand's lamp, in a basin of porcelain, to a temperature equal to 300 Fahrenheit; and if a thermometer is not used, the proper degree may be easily ascertained by keeping a piece of wood in contact with the bottom of the dish; as long as the colour of the wood remains unaltered, the heat is not too high; but when the wood begins to be charred, the process must be stopped. A small quantity of water will perhaps remain in the soil even after this operation, but it always affords useful comparative results; and if a higher temperature were employed, the vegetable or animal matter would undergo decomposition, and, in consequence, the experiment be wholly unsatisfactory.

"The loss of weight in the process should be carefully noted, and when in 400 grains of soil it reaches as high as 50, the soil may be considered as in the greatest degree absorbent, and retentive of water, and will generally be found to contain much vegetable or animal matter, or a large proportion of aluminous earth. When the loss is only from 20 to 10, the land may be considered as only slightly absorbent and retentive, and siliceous earth probably forms the greatest part of it.

"2. None of the loose stones, gravel, or large vegetable fibres should be divided from the pure soil till after the water is drawn off: for these bodies are themselves often highly absorbent and retentive, and, in consequence, influence the fertility of the land. The next process, however, after that of heating, should be their separation, which may be easily accomplished by the sieve, after the soil has been gently bruised in a mortar. The weights of the vegetable fibres, or wood, and of the gravel and stones, should be separately noted down, and the nature of the last ascertained; if calcareous, they will effervesce with acids; if siliceous, they will be sufficiently hard to scratch glass; and if of the common aluminous class of stones, they will be soft, easily cut with a knife, and incapable of effervescing with acids.

"3. The greater number of soils, besides gravel and stones, contain larger or smaller proportions of sand, of different degrees of fineness: and it is a necessary operation, the next in the process of analysis, to detach them from the parts in a state of more minute division, such as clay, loam, marl, vegetable and animal matter, and the matter soluble in water. This may be effected in a way sufficiently accurate, by boiling the soil in three or four times its weight of water; and when the texture of the soil is broken down, and the water cool, by agitating the parts together, and then suffering them to rest. In this case, the coarse sand will generally separate in a minute, and the finer in two or three minutes, whilst the highly-divided earthy, animal, or vegetable matter will remain in a state of mechanical suspension for a much longer time; so that, by pouring the water from the bottom of the vessel, after one, two, or three minutes, the sand will be principally separated from the other substances, which, with the water containing them, must be poured into a filter, and, after the water has passed through, collected, dried, and weighed. The sand must likewise be weighed, and the respective quantities noted down. The water of lixiviation must be preserved, as it will be found to contain the saline and soluble animal or vegetable matters, if any exist in the soil.

"4. By the process of washing and filtration, the soil is separated into two portions, the most important of which is generally the finely-divided matter. A minute analysis of the sand is seldom or never necessary, and its nature may be detected in the same manner as that of the stones or gravel. It is always either siliceous sand, or calcareous sand, or a mixture of both. If it consist wholly of carbonate of lime, it will be rapidly soluble in muriatic acid, with effervescence; but if it consist partly of this substance, and partly of siliceous matter, the respective quantities may be ascertained by weighing the residuum after the action of the acid, which must be applied till the mixture has acquired a sour taste, and has ceased to effervesce. This residuum is the siliceous part; it must be washed, dried, and heated strongly in a crucible; the difference between the weight of it, and the weight of the whole, indicates the proportion of calcareous sand.

"5. The finely-divided matter of the soil is usually very compound in its nature; it sometimes contains all the four primitive earths of soils, as well as animal and vegetable matter; and to ascertain the proportion of these with tolerable accuracy, is the most difficult part of the subject.

"The first process to be performed, in this part of the analysis, is the exposure of the fine matter of the soil to the action of muriatic acid. This substance should be poured upon the earthy matter in an evaporating basin, in a quantity equal to twice the weight of the earthy matter; but diluted with double its volume of water. The mixture should be often stirred, and suffered to remain for an hour, or an hour and a half, before it is examined.

"If any carbonate of lime or of magnesia exist in the soil, they will have been dissolved in this time by the acid, which sometimes takes up likewise a little oxide of iron; but very seldom any alumina.

"The fluid should be passed through a filter; the solid matter collected, washed with rain-water, dried at a moderate heat, and weighed. Its loss will denote the quantity of solid matter taken up. The washings must be added to the solution, which, if not sour to the taste, must be made so by the addition of fresh acid, when a little solution of prussiate of potassa and iron must be mixed with the whole. If a blue precipitate occurs, it denotes the presence of oxide of iron, and the solution of the prussiate must be dropped in till no farther effect is produced. To ascertain its quantity, it must be collected in the same manner as other solid precipitates, and heated red; the result is oxide of iron, which may be mixed with a little oxide of manganese.

"Into the fluid freed from oxide of iron, a solution of neutralized carbonate of potash must be poured till all effervescence ceases in it, and till its taste and smell indicate a considerable excess of alcaline salt.

"The precipitate that falls down is carbonate of lime, it must be collected on the filter, and dried at a heat below that of redness.

"The remaining fluid must be boiled for a quarter of an hour, when the magnesia, if any exist, will be precipitated from it, combined with carbonic acid, and its quantity is to be ascertained in the same manner as that of the carbonate of lime.

"If any minute proportion of alumina should, from peculiar circumstances, be dissolved by the acid, it will be found in the precipitate with the carbonate of lime, and it may be separated from it by boiling it for a few minutes with soap lye, sufficient to cover the solid matter; this substance dissolves alumina, without acting upon carbonate of lime.

"Should the finely-divided soil be sufficiently calcareous to effervesce very strongly with acids, a very simple method may be adopted for ascertaining the quantity of carbonate of lime, and one sufficiently accurate in all common cases.

"Carbonate of lime, in all its states, contains a determinate proportion of carbonic acid, *i. e.*, nearly 43 *per cent.*, so that when the quanity of this elastic fluid, given out by any soil during the solution of its alcareous matter in an acid is known, either in weight or measure, the uantity of carbonate of lime may be easily discovered.

"When the process by diminution of weight is employed, two parts f the acid and one part of the matter of the soil must be weighed in wo separate bottles, and very slowly mixed together till the efferves-ence ceases; the difference between their weight before and after he experiment, denotes the quantity of carbonic acid lost; for every four grains and a quarter of which, 10 grains of carbonate of lime must be estimated.

"6. After the calcareous parts of the soil have been acted upon by muriatic acid, the next process is to ascertain the quantity of finely-divided insoluble animal and vegetable matter that it contains.

"This may be done with sufficient precision, by strongly igniting it in a crucible over a common fire till no blackness remains in the mass. It should be often stirred with a metallic rod, so as to expose new surfaces continually to the air; the loss of weight that it undergoes denotes the quantity of the substance that it contains destructible by fire and air.

"It is not possible, without very refined and difficult experiments, to ascertain whether this substance is wholly animal or vegetable matter, or a mixture of both. When the smell emitted during the incineration is similar to that of burnt feathers, it is a certain indication of some substance either animal or analogous to animal matter; and a copious blue flame at the time of ignition, almost always denotes a considerable proportion of vegetable matter. In cases when it is necessary that the experiment should be very quickly performed, the destruction of the decomposable substances may be assisted by the agency of nitrate of ammonia, which at the time of ignition may be thrown gradually upon the heated mass in the quantity of 20 grains for every hundred of residual soil. It accelerates the dissipation of the animal and vegetable matter, which it causes to be converted into elastic fluids; and it is itself at the same time decomposed and lost.

"7. The substances remaining after the destruction of the vegetable and animal matter, are generally minute particles of earthy matter, containing usually alumina and silica, with combined oxide of iron or of manganese.

"To separate these from each other, the solid matter should be boiled for two or three hours with sulphuric acid, diluted with four times its weight of water; the quantity of the acid should be regulated by the quantity of solid residuum to be acted on, allowing for every hundred grains two drachms, or 120 grains, of acid:

"The substance remaining after the action of the acid, may be considered as siliceous: and it must be separated and its weight ascertained, after washing and drying in the usual manner.

"The alumina, and the oxide of iron and manganesum, if any exist, are all dissolved by the sulphuric acid; they may be separated by succinate of ammonia, added to excess, which throws down the oxide of iron; and by soap lye, which will dissolve the alumina, but not the oxide of manganese: the weights of the oxides ascertained after they have been heated to redness will denote their quantities.

"Should any magnesia and lime have escaped solution in the muriatic acid, they will be found in the sulphuric acid; this, however, is rarely the case; but the process for detecting them, and ascertaining their quantities, is the same in both instances.

"The method of analysis by sulphuric acid, is sufficiently precise for all usual experiments; but if very great accuracy be an object, dry carbonate of potassa must be employed as the agent, and the residuum of the incineration (6) must be heated red for a half hour, with four times its weight of this substance, in a crucible of silver, or of well baked porcelain. The mass obtained must be dissolved in muriatic acid, and the solution evaporated till it is nearly solid; distilled water must then be added, by which the oxide of iron and all the earths, except silica, will be dissolved in combination as muriates. The silica, after the usual process of lixiviation, must be heated red; the other substances may be separated in the same manner as *from the muriatic* and sulphuric solutions.

"This process is the one usually employed by chemical philosophers for the analysis of stones.

"8. If any saline matter, or soluble vegetable or animal matter is suspected in the soil, it will be found in the water of lixiviation used for separating the sand.

"This water must be evaporated to dryness in a proper dish, at a heat below its boiling point.

"If the solid matter obtained is of a brown colour and inflammable, it may be considered as partly vegetable extract. If its smell, when exposed to heat, be like that of burnt feathers, it contains animal or albuminous matter; if it be white, crystalline, and not destructible by heat, it may be considered as principally saline matter.

"9. Should sulphate or phosphate of lime be suspected in the entire soil, the detection of them requires a particular process *upon it*. A given weight of it, for instance, 400 grains, must be heated red for half an hour in a crucible, mixed with one-third of powdered charcoal. The mixture must be boiled for a quarter of an hour, in a half pint of water, and the fluid collected through the filter, and exposed for some days to the atmosphere in an open vessel. If any notable quantity of sulphate of lime (gypsum) existed in the soil, a white precipitate will gradually form in the fluid, and the weight of it will indicate the proportion.

"Phosphate of lime, if any exist, may be separated from the soil after the process for gypsum. Muriatic acid must be digested upon the soil, in quantity more than sufficient to saturate the soluble earths; the solution must be evaporated, and water poured upon the solid matter. This fluid will dissolve the compounds of earths with the muriatic acid, and leave the phosphate of lime untouched.

"It would not fall within the limits assigned to this Lecture, to detail any processes for the detection of substances which may be accidentally mixed with the matters of soils. Other earths and metallic oxides are now and then found in them, but in quantities too minute to bear any relation to fertility or barrenness, and the search for them would make the analysis much more complicated without rendering it more useful.

"10. When the examination of a soil is completed, the products should be numerically arranged, and their quantities added together, and if they nearly equal the original quantity of soil, the analysis may be considered as accurate. It must, however, be noticed, that when phosphate or sulphate of lime are discovered by the independent process just described (9), a correction must be made for the general process, by subtracting a sum equal to their weight from the quantity of carbonate of lime, obtained by precipitation from the muriatic acid.

"In arranging the products, the form should be in the order of the experiments by which they were procured.

"Thus, I obtained from 400 grains of a good siliceous sandy soil, from a hop garden near Tunbridge, Kent,

		Grains.
Of water of absorption		19
— loose stones and gravel principally siliceous		53
— undecompounded vegetable fibres		14
— fine siliceous sand		212
Of minutely divided matter separated by agitation and filtration, and consisting of		
Carbonate of lime	19	
Carbonate of magnesia	3	
Matter destructible by heat, principally vegetable	15	
Silica	21	
Alumina	13	
Oxide of iron	5	
Soluble matter, principally common salt and vegetable extract	3	
Gypsum	2	
	—	81
Amount of all the products		379
Loss		21

"The loss in this analysis is not more than usually occurs, and it depends upon the impossibility of collecting the whole quantities of the different precipitates; and upon the presence of more moisture than is accounted for in the water of absorption, and which is lost in the different processes.

"When the experimenter is become acquainted with the use of the different instruments, the properties of the re-agents, and the relations between the external and chemical qualities of soils, he will seldom find it necessary to perform, in any one case, all the processes that have been described. When his soil, for instance, contains no notable proportion of calcareous matter, the action of the muriatic acid (7) may be omitted. In examining peat soils, he will principally have to attend to the operation by fire and air (8); and in the analysis of chalks and loams, he will often be able to omit the experiment by sulphuric acid (9).

"In the first trials that are made by persons unacquainted with chemistry, they must not expect much precision of result. Many difficulties will be met with: but in overcoming them, the most useful kind of practical knowledge will be obtained; and nothing is so instructive in experimental science, as the detection of mistakes. The correct analyst ought to be well grounded in general chemical information; but, perhaps, there is no better mode of gaining it, than that of attempting original investigations. In pursuing his experiments, he will be continually obliged to learn the properties of the substances he is employing or acting upon; and his theoretical ideas will be more valuable in being connected with practical operations, and acquired for the purpose of discovery.

"Plants being possessed of no locomotive powers, can grow only in places where they are supplied with food; and the soil is necessary to their existence, both as affording them nourishment, and enabling them to fix themselves in such a manner as to obey those mechanical laws by which their radicles are kept below the surface, and their leaves exposed to the free atmosphere. As the systems of roots, branches, and leaves, are very different in different vegetables, so they flourish most in different soils; the plants that have bulbous roots require a looser and a lighter soil than such as have fibrous roots; and the plants possessing only short fibrous radicles demand a firmer soil than such as have tap roots, or extensive lateral roots.

"A good turnip soil from Holkham, Norfolk, afforded me eight parts out of nine siliceous sand; and the finely-divided matter consisted

Of carbonate of lime	63
— silica	15
— alumina	11
— oxide of iron	3
— vegetable and saline matter	5
— moisture	3

"I found the soil taken from a field at Sheffield-place, in Sussex, remarkable for producing flourishing oaks, to consist of six parts of sand, and one part of clay and finely-divided matter. And 100 parts of the entire soil, submitted to analysis, produced.

	Parts.
Silica	54
Alumina	28
Carbonate of lime	3
Oxide of iron	5
Decomposing vegetable matter	4
Moisture and loss	3

"An excellent wheat soil, from the neighbourhood of West Drayton, Middlesex, gave three parts in five of siliceous sand; and the finely-divided matter consisted of

Carbonate of lime	28
Silica	32
Alumina	29
Animal or vegetable matter and moisture	11

"Of these soils the last was by far the most, and the first the least, coherent in texture. In all cases the constituent parts of the soil which give tenacity and coherence are the finely-divided matters; and they possess the power of giving those qualities in the highest degree when they contain much alumina. A small quantity of finely-divided matter is sufficient to fit a soil for the production of turnips and barley; and I have seen a tolerable crop of turnips on a soil containing 11 parts out of 12 sand. A much greater proportion of sand, however, always produces absolute sterility. The soil of Bagshot heath, which is entirely devoid of vegetable covering, contains less than $\frac{1}{20}$ of finely-divided matter. 400 parts of it, which had been heated red, afforded me 380 parts of coarse siliceous sand, nine parts of fine siliceous sand,

and 11 parts of impalpable matter, which was a mixture of ferruginous clay, with carbonate of lime. Vegetable or animal matters, when finely-divided, not only give coherence, but likewise softness and penetrability; but neither they nor any other part of the soil must be in too great proportion; and a soil is unproductive if it consist entirely of impalpable matters.

" Pure alumina or silica, pure carbonate of lime, or carbonate of magnesia, are incapable of supporting healthy vegetation.

" No soil is fertile that contains as much as 19 parts out of 20 of any of the constituents that have been mentioned.

" It will be asked, are the pure earths in the soil merely active as mechanical or indirect chemical agents, or do they actually afford food to the plant? This is an important question; and not difficult of solution.

" The earths consist, as I have before stated, of metals united to oxygen; and these metals have not been decomposed; there is consequently no reason to suppose that the earths are convertible into the elements of organized compounds, into carbon, hydrogen, and azote.

" Plants have been made to grow in given quantities of earth. They consume very small portions only; and what is lost may be accounted for by the quantities found in their ashes; that is to say, it has not been converted into any new products.

" The carbonic acid united to lime or magnesia, if any stronger acid happens to be formed in the soil during the fermentation of vegetable matter which will disengage it from the earths, may be decomposed; but the earths themselves cannot be supposed convertible into other substances, by any process taking place in the soil.

" In all cases the ashes of plants contain some of the earths of the soil in which they grow; but these earths, as may be seen from the table of the ashes afforded by different plants given in the last Lecture*, never equal more than $\frac{1}{50}$ of the weight of the plant consumed.

" If they be considered as necessary to the vegetable, it is as giving hardness and firmness to its organization. Thus, it has been mentioned that wheat, oats, and many of the hollow grasses, have an epidermis principally of siliceous earth; the use of which seems to be to strengthen them, and defend them from the attacks of insects and parasitical plants.

" Many soils are popularly distinguished as *cold;* and the distinction, though at first view it may appear to be founded on prejudice, is really just.

" Some soils are much more heated by the rays of the sun, all other circumstances being equal, than others; and soils brought to the same degree of heat cool in different times, *i. e.* some cool much faster than others.

" This property has been very little attended to in a philosophical point of view; yet it is of the highest importance in agriculture. In general, soils that consist principally of a stiff white clay are difficultly heated; and being usually very moist they retain their heat only for a short time. *Chalks* are similar in one respect, that they are difficultly heated; but being drier they retain their heat longer, less being consumed in causing the evaporation of their moisture.

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* See Sir Humphry Davy's *Elements of Agricultural Chemistry*, 4to., p. 102.

"A black soil, containing much soft vegetable matter, is most heated by the sun and air; and the coloured soils, and the soils containing much carbonaceous matter, or ferruginous matter, exposed under equal circumstances to sun, acquire a much higher temperature than pale-coloured soils.

"When soils are perfectly dry, those that most readily become heated by the solar rays likewise cool most rapidly; but I have ascertained by experiment, that the darkest-coloured dry soil (that which contains abundance of animal or vegetable matter, substances which most facilitate the diminution of temperature,) when heated to the same degree, provided it be within the common limits of the effect of solar heat, will cool more slowly than a wet pale soil entirely composed of earthy matter.

"I found that a rich black mould, which contained nearly ¼ of vegetable matter, had its temperature increased in an hour from 65° to 88° by exposure to sunshine; whilst a chalk soil was heated only to 69° under the same circumstances. But the mould, removed into the shade, where the temperature was 62°, lost, in half an hour, 15°; whereas the chalk, under the same circumstances, had lost only 4°.

"Brown fertile soil, and a cold barren clay were each artificially heated to 88°, having been previously dried; they were then exposed in a temperature of 57°; in half an hour the dark soil was found to have lost 9° of heat; the clay had lost only 6°. An equal portion of the clay containing moisture, after being heated to 88°, was exposed in a temperature of 55°; in less than a quarter of an hour it was found to have gained the temperature of the room. The soils in all these experiments were placed in small tin-plate trays, two inches square and half an inch in depth; and the temperature ascertained by a delicate thermometer.

"Nothing can be more evident, than that the genial heat of the soil, particularly in spring, must be of the highest importance to the rising plant. And when the leaves are fully developed, the ground is shaded; and any injurious influence, which in the summer might be expected from too great a heat, entirely prevented: so that the temperature of the surface, when bare and exposed to the rays of the sun, affords at least one indication of the degrees of its fertility; and the thermometer may be sometimes a useful instrument to the purchaser or improver of lands.

"The moisture in the soil influences its temperature; and the manner it which it is distributed through, or combined with, the earthy materials, is of great importance in relation to the nutriment of the plant. If water is too strongly attracted by the earths, it will not be absorbed by the roots of the plants; if it is in too great quantity, or too loosely united to them, it tends to injure or destroy the fibrous by parts of the roots.

"There are two states in which water seems to exist in the earths, and in animal and vegetable substances; in the first state it is united chemical, in the other by cohesive, attraction.

"If pure solution of ammonia or potassa be poured into a solution of alum, alumina falls down combined with water; and the powder dried by exposure to air will afford more than half its weight of water by distillation; in this instance the water is united by chemical attraction. The moisture which wood, or muscular fibre, or gum, that have been heated to 212°, afford by distillation at a red heat, is likewise water, the elements of which were united in the substance by chemical combination.

"When pipe-clay, dried at the temperature of the atmosphere, is brought in contact with water, the fluid is rapidly absorbed; this is owing to cohesive attraction. Soils in general, vegetable, and animal substances, that have been dried at a heat below that of boiling water, increase in weight by exposure to air, owing to their absorbing water existing in the state of vapour in the air, in consequence of cohesive attraction.

"The water *chemically combined* amongst the elements of soils, unless in the case of the decomposition of animal or vegetable substances, cannot be absorbed by the roots of plants; but that *adhering* to the parts of the soil is in constant use in vegetation. Indeed there are few mixtures of the earths found in soils that contain any chemically combined water; water is expelled from the earths by most substances that combine with them. Thus, if a combination of lime and water be exposed to carbonic acid, the carbonic acid takes the place of water, and compounds of alumina and silica, or other compounds of the earths, do not chemically unite with water; and soils, as it has been stated, are formed either by earthy carbonates, or compounds of the pure earths and metallic oxides.

"When saline substances exist in soils, they may be united to water both chemically and mechanically; but they are always in too small a quantity to influence materially the relations of the soil to water.

"The power of the soil to absorb water by cohesive attraction, depends in great measure upon the state of division of its parts; the more divided they are, the greater is their absorbent power. The different constituent parts of soils likewise appear to act, even by cohesive attraction, with different degrees of energy. Thus vegetable substances seem to be more absorbent than animal substances; animal substances more so than compounds of alumina and silica; and compounds of alumina and silica more absorbent than carbonates of lime and magnesia; these differences may, however, possibly depend upon the differences in their state of division, and upon the surface exposed.

"The power of soils to absorb water from air, is much connected with fertility. When this power is great, the plant is supplied with moisture in dry seasons; and the effect of evaporation in the day is counteracted by the absorption of aqueous vapour from the atmosphere, by the interior parts of the soil during the day, and by both the exterior and interior during night.

"The stiff clays approaching to pipe-clays in their nature, which take up the greatest quantity of water when it is poured upon them in a fluid form, are not the soils which absorb most moisture from the atmosphere in dry weather. They cake, and present only a small surface to the air, and the vegetation on them is generally burnt up almost as readily as on sands.

"The soils that are most efficient in supplying the plant with water by atmospheric absorption, are those in which there is a due mixture of sand, finely-divided clay, and carbonate of lime, with some animal or vegetable matter; and which are so loose and light as to be freely permeable to the atmosphere. With respect to this quality, carbonate of lime and animal and vegetable matter are of great use in soils; they give absorbent power to the soil without giving it likewise tenacity; sand, which also destroys tenacity, on the contrary, gives little absorbent power.

"I have compared the absorbent powers of many soils with respect to atmospheric moisture, and I have always found it greatest in the most fertile soils; so that it affords one method of judging of the productiveness of land.

"1000 parts of a celebrated soil from Ormiston, in East Lothian, which contained more than half its weight of finely-divided matter, of which 11 parts were carbonate of lime, and 9 parts vegetable matter, when dried at 212°, gained in an hour by exposure to air, saturated with moisture, at temperature 62°, 18 grains.

"1000 parts of a very fertile soil from the banks of the river Parret, in Somersetshire, under the same circumstances, gained 16 grains.

"1000 parts of a soil from Mersea, in Essex, worth 45 shillings an acre, gained 13 grains.

"1000 grains of a fine sand from Essex, worth 28 shillings an acre, gained 11 grains.

"1000 of a coarse sand, worth 15 shillings an acre, gained only eight grains.

"1000 of the soil of Bagshot-heath gained only three grains.

"Water, and the decomposing animal and vegetable matter existing in the soil, constitute the true nourishment of plants; and as the earthy parts of the soil are useful in retaining water, so as to supply it in the proper proportions to the roots of the vegetables, so they are likewise efficacious in producing the proper distribution of the animal or vegetable matter; when equally mixed with it they prevent it from decomposing too rapidly; and by their means the soluble parts are supplied in proper proportions.

"Besides this agency, which may be considered as mechanical, there is another agency between soils and organizable matters, which may be regarded as chemical in its nature. The earths, and even the earthy carbonates, have a certain degree of chemical attraction for many of the principles of vegetable and animal substances. This is easily exemplified in the instance of alumina and oil; if an acid solution of alumina be mixed with a solution of soap, which consists of oily matter and potassa, the oil and the alumina will unite and form a white powder, which will sink to the bottom of the fluid.

"The extract from decomposing vegetable matter when boiled with pipe-clay or chalk, forms a combination by which the vegetable matter is rendered more difficult of decomposition and of solution. Pure silica and siliceous sands have little action of this kind; and the soils which contain the most alumina and carbonate of lime, are those which act with the greatest chemical energy in preserving manures. Such soils merit the appellation which is commonly given to them of rich soils; for the vegetable nourishment is long preserved in them, unless taken up by the organs of plants. Siliceous sands, on the contrary, deserve the term hungry, which is commonly applied to them; for the vegetable and animal matters they contain not being attracted by the earthy constituent parts of the soil, are more liable to be decomposed by the action of the atmosphere, or carried off from them by water.

"In most of the black and brown rich vegetable moulds, the earths seem to be in combination with a peculiar extractive matter, afforded luring the decomposition of vegetables: this is slowly taken up, or ttracted from the earths by water, and appears to constitute a prime ause of the fertility of the soil.

" The standard of fertility of soils for different plants must vary vith the climate; and must be particularly influenced by the quantity f rain.

" The power of soils to absorb moisture ought to be much greater n warm or dry countries, than in cold and moist ones; and the quanity of clay, or vegetable or animal matter they contain, greater. Soils lso on declivities ought to be more absorbent than in plains or in the ottom of valleys. Their productiveness likewise is influenced by he nature of the subsoil or the stratum on which they rest.

" When soils are immediately situated upon a bed of rock or stone, hey are much sooner rendered dry by evaporation, than where the ubsoil is of clay or marl; and a prime cause of the great fertility of he land in the moist climate of Ireland, is the proximity of the rocky trata to the soil.

" A clayey subsoil will sometimes be of material advantage to a sandy oil; and in this case it will retain moisture in such a manner as to be apable of supplying that lost by the earth above, in consequence of vaporation, or the consumption of it by plants.

" A sandy or gravelly subsoil, often corrects the imperfections of too reat a degree of absorbent power in the true soil.

" In calcareous countries, where the surface is a species of marl, he soil is often found only a few inches above the limestone; and its ertility is not impaired by the proximity of the rock; though in a less bsorbent soil, this situation would occasion barrenness; and the sandtone and limestone hills in Derbyshire and North Wales may be easily listinguished at a distance in summer by the different tints of the veetation. The grass on the sandstone hills usually appears brown and urnt up; that on the limestone hills, flourishing and green.

" In devoting the different parts of an estate to the necessary crops, t is perfectly evident from what has been said, that no general princile can be laid down, except when all the circumstances of the nature, omposition, and situation of the soil and subsoil are known.

" The methods of cultivation likewise must be different for differnt soils. The same practice which will be excellent in one case may e destructive in another.

" Deep ploughing may be a very profitable practice in a rich thick oil; and in a fertile shallow soil, situated upon cold clay or sandy suboil, it may be extremely prejudicial.

" In a moist climate where the quantity of rain that falls annually quals from 40 to 60 inches, as in Lancashire, Cornwall, and some parts f Ireland, a siliceous sandy soil is much more productive than in dry listricts; and in such situations wheat and beans will require a less coerent and absorbent soil than in drier situations; and plants, having ulbous roots, will flourish in a soil containing as much as 14 parts ut of 15 of sand.

" Even the exhausting powers of crops will be influenced by like ircumstances. In cases where plants cannot absorb sufficient moisure, they must take up more manure. And in Ireland, Cornwall, and he western Highlands of Scotland, corn will exhaust less than in dry nland situations. Oats, particularly in dry climates, are impoverishng in a much higher degree than in moist ones."

APPENDIX,

CONTAINING

EQUIVALENT NUMBERS OF VEGETABLE AND ANIMAL PRODUCTS, AND THEIR COMBINATIONS;

TABULAR VIEW

OF THE

EQUIVALENT NUMBERS OF VEGETABLE AND ANIMAL PRODUCTS, AND THEIR COMBINATIONS.

SUBSTANCES	Equivalent Number	COMPOSITION
I. Gum	90?	
Bigummate of lead	292	180 gum. + 112 ox. of lead.
II. Sugar	81?	
Saccharate of lead	192	81 sugar + 112 ox. of lead.
III. Starch	144?	
Binamilate of lead	400	288 starch + 112 ox. of lead.
IV. Tannin	215.3?	
Tannate of lead	327.3	215.3 tannin + 112 ox. of lead.
V. Wax	146?	
VI. Oil?		
VII. Camphoric acid?		
VIII. Succinic acid	50?	
Succinate of ammonia	67	50 S. A. + 17 ammon.
——— potassa	98	50 S. A. + 48 P.
——— soda	82	50 S. A. + 32 S.
——— lime	78	50 S. A. + 28 L.

Equivalent Numbers, &c. (continued.)

SUBSTANCES	Equivalent Number	COMPOSITION
Succinate of baryta	128	50 S. A. + 78 B.
——— strontia	102	50 S. A. + 52 S.
——— magnesia	70	50 S. A. + 20 M.
——— manganese	86	50 S. A. + 36 O. M.
——— iron	86	50 S. A. + 36 O. I.
——— zinc	92	50 S. A. + 42 O. Z.
——— tin	117	50 S. A. + 67 O. T.
——— copper?	122	50 S. A. + 72 O. C.
——— lead	162	50 S. A. + 112 O. L.
IX. MORPHIA	324?	
X. MECONIC ACID	23?	
XI. STRICHNIA	381?	
XII. BRUCIA?		
XIII. DELPHIA?		
XIV. MELLITIC ACID?		
XV. TARTARIC ACID	67	
Tartrate of ammonia	84	67 T. A. + 17 Amm.
——— potassa	115	67 T. A. + 48 P.
Bi-tartrate of potassa	182	134 T. A. + 48 P.
Tartrate of potassa and ammonia	199	134 T. A. + 48 P + 17 Amm.
——— soda	99	67 T. A. + 32 S.
——— potassa and soda	214	134 T. A. + 32 S. + 48 P.

Equivalent Numbers, &c. (continued.)

SUBSTANCES.	Equivalent Number	COMPOSITION.
Tartrate of lime	95	67 T. A.+28 L.
——— and potassa	210	134 T. A.+28 L.+48 P.
—— baryta	145	67 T. A.+78 B.
—— strontia	119	67 T. A.+52 S.
—— magnesia	87	67 T. A.+20 M.
—— manganese	103	67 T. A.+36 O. M.
—— iron	103	67 T. A.+36 O. I.
——— and potassa.	218	134 T. A.+36 O. I.+48 P.
—— zinc	109	67 T. A.+42 O. Z.
—— tin	134	67 T. A.+67 O. T.
——— and potassa	249	134 T. A.+67 O. T.+48 P.
—— copper	214	134 T. A.+80 perox. C.
—— lead	179	67 T. A.+112 O. L.
——— and potassa	294	134 T. A.+112 O. L.+48 P.
—— antimony	123	67 T. A.+56 O. A.
———— and potassa	238	134 T. A.+56 O. A.+48 P.
—— bismuth	147	67 T. A.+80 O. B.
—— cobalt	107.5	67 T. A.+40.5 O. C.
—— uranium?		
—— titanium?		
—— cerium?		
—— nickel	104.6	67 T. A.+37.6 O. N.
—— mercury	275	67 T. A.+208 O. M.
———— and potassa.	390	134 T. A.+208 O. M.+48 P.
—— silver	184.3	67 T. A.+117.3 O. S.
—— silver and potassa	299.3	134 T. A.+117.3 O. S.+48 P.

Equivalent Numbers. &c. (continued.)

SUBSTANCES.	Equivalent Number.	COMPOSITION.
XVI. Oxalic Acid	38.?	
Oxalate of ammonia	55	38 O. A. + 17 Am.
———— potassa	86	38 O. A. + 48 P.
———— soda	70	38 O. A. + 32 S.
———— lime	66	38 O. A. + 28 L.
———— baryta	116	38 O. A. + 78 B.
———— strontia	90	38 O. A. + 52 S.
———— magnesia	58	38 O. A. + 20 M.
———— manganese	74	38 O. A. + 36 O. M.
———— iron	74	38 O. A. + 36 O. I.
———— zinc	80	38 O. A. + 42 O. Z.
———— tin	105	38 O. A. + 67 O. T.
———— copper	156	76 O. A. + 80 Perox. C.
———————— and ammonia	211	156 Ox. Cop. + 55 Oxal. am.
———————— and potassa	242	156 Ox. Cop. + 86 Ox. Pot.
———————— and soda	226	156 Ox. Cop. + 70 Ox. Sod.
———— lead	150	38 O. A. + 112 O. L.
———— antimony	94	38 O. A. + 56 O. Ant.
———— bismuth	118	38 O. A. + 80 O. B.
———— cobalt	78.5	38 O. A. + 40.5 O. C.
———— uranium?		
———— nickel	756	38 O. A. + 37.6 O. N.
———— mercury	246	38 O. A. + 208 O. M.
———— silver	155.3	38 O. A. + 117.3 O. S.
XVII. Citric Acid	59?	

Equivalent, Numbers, &c. (continued.)

SUBSTANCES.	Equivalent Number	COMPOSITION.
Citrate of ammonia	76	59 C. A. + 17 Am.
——— potassa	107	59 C. A. + 48 P.
——— soda	91	59 C. A. + 32 S.
——— lime	87	59 C. A. + 28 L.
——— baryta	137	59 C. A. + 78 B.
——— strontia	111	59 C. A. + 52 S.
——— magnesia	79	59 C. A. + 20 M.
——— manganese	95	59 C. A. + 36 O. M.
——— iron	95	59 C. A. + 36 O. I.
——— zinc	101	59 C. A. + 42 O. Z.
——— tin	126	59 C. A. + 67 O. T.
——— copper	198	118 C. A. + 80 per ox. C.
——— lead	171	59 C. A. + 112 O. L.
——— antimony?		
——— bismuth	139	59 C. A. + 80 O. B.
——— cobalt	99.5	59 C. A. + 40.5 O. C.
——— uranium?		
——— nickel	96.6	59 C. A. + 37.6 O. N.
——— mercury	267	59 C. A. + 208 O. M.
——— silver	176.3	59 C. A. + 117.3 O. S.
XVIII. MALIC ACID	71.1?	
XIX. GALLIC ACID	64.3?	
XX. BENZOIC ACID	119?	
Benzoate of ammonia	136	119 B. A. + 17 Amm.
——— potassa	167	119 B. A. + 48 P.

Equivalent Numbers, &c. (continued.)

SUBSTANCES.	Equivalent Number.	COMPOSITION.
Benzoate of soda	51	119 B. A. + 32 S.
——— lime	147	119 B. A. + 28 L.
——— baryta	197	119 B. A. + 78 B.
——— lead	231	119 B. A. + 112 O. L.
XXI. Acetic Acid	51.5?	
Acetate of ammonia	68.5	51.5 A. A. + 17 Amm.
——— potassa	99.5	51.5 A. A. + 48 P.
——— soda	83.5	51.5 A. A. + 32 S.
——— lime	79.5	51.5 A. A. + 28 L.
——— baryta	129.5	51.5 A. A. + 78 B.
——— strontia	103.5	51.5 A. A. + 52 S.
——— magnesia	71.5	51.5 A. A. + 20 M.
——— manganese	87.5	51.5 A. A. + 36 O. M.
——— iron	87.5	51.5 A. A. + 36 O. I.
——— zinc	93.5	51.5 A. A. + 42 O. Z.
——— tin	118.5	51.5 A. A. + 67 O. T.
——— copper	183	103 A. A. + 80 Perox. C.
——— lead	163.5	51.5 A. A. + 112 O. L.
——— bismuth	131.5	51.5 A. A. + 80 O. B.
——— mercury	259.5	51.5 A. A. + 208 O. M.
——— silver	168.8	51.5 A. A. + 117.3 O. S.
——— alumina?		

XXII. Formic Acid? .... Probably a compound of Malic and Acetic Acids.

XXIII. Uric Acid? .... | 35?

Note to SECT. 46—p. 17.

* Two years ago, when Mr. Brande published the first edition of his Manual, the atomic theory could not well be represented as an independent collection of facts, and much less can it be considered so at present. The doctrine of definite proportions is now satisfactorily established, and the ratio of combining quantities is found to proceed in such regular progression that many of the phenomena of Chemistry may be submitted to calculation, and some of its abstrusest parts elucidated upon mathematical principles.

A very important law has been found to govern Chemical combinations, in virtue of which, when bodies combine in different proportions, the larger proportion of one of the ingredients has a simple arithmetical ratio to the lesser proportion: The second quantity being a simple multiple of the first, and if there is a third or fourth proportion, the same ratio continues between them. If 100 of *a* combine in the first proportion with 8 of *b*, in the second proportion 100 of *a* will combine with 16 of *b*, in the third with 24, in the fourth with 32; these proportions having to each other the simple ratio of 1, 2, 3, 4.

The operation of this principle appeared with striking and instructive evidence in the tables of Dr. Richter. They were formed from a series of numerous experiments on the reciprocal decomposition of salts, and show the weight of each base capable of saturating one hundred parts of each acid; and the weight of each acid, capable of saturating one hundred of each base. He threw the results into tables, and observed that in *all*, the bases and the acids followed the same order: and further that the numbers in each table constitute a series, having the same ratio to each other in all the tables. Thus supposing in the table of sulphates, one hundred parts of acid were saturated by one hundred of soda, two hundred of potassa and three hundred of baryta; then in the table of nitrates the same ratio would hold good, and the soda, potassa and baryta, would there also stand to each other in the relation of one, two and three.

Thus was explained, why when two neutral salts decompose each other, the newly formed salts are also neutral; for the same proportion of the bases that saturate a given weight of one acid will saturate a given weight also of all the other acids. Hence numbers may be attached to each acid and to each base, indicating the weight of it, which will saturate the numbers attached to all the other acids and bases. Upon this principle elementary works on Chemistry contain tables of the representative numbers of bodies.

Mr. Higgins in 1789, published that Chemical attraction only prevailed between the ultimate particles of simple elementary matter, and between compound atoms. Mr. Dalton in 1804 greatly developed and improved this doctrine, and since then some of the most eminent Chemical philosophers have directed their attention to the definite proportions in which bodies unite that form several compounds. Seventy parts of potash, for example, unite to thirty of carbonic acid, and to sixty, but not to any intermediate proportions, when two bodies combine only in one proportion, the most simple supposition is, that they combine atom to atom singly, that is, one atom of the one with one atom of the other; when they combine in two proportions, it may be supposed that the first combination is that of one atom of the one with one atom of the other; and the second that of one atom of the one with two of the other; in the third of one atom with three, &c.; and no combinations in proportions different from these will exist.

The same law was inferred by Dr. Wollaston, from the investigation of certain saline compounds. He had observed, that when they are partially decomposed, the quantity of one of the ingredients abstracted is exactly half the quantity of it which the compound contains. In producing, for example, the partial decomposition, by heat, of the compound of potash with carbonic acid, a certain quantity of carbonic acid is expelled from it; and in submitting it after this to a more powerful decomposing force, that of the action of a strong acid, another quantity of carbonic acid is expelled, which is exactly equal to the former; apparently proving that the potash combines with the carbonic acid in two proportions, of which the one is just double the other.

Gay-Lussac afterwards observed a relation in the combinations of aerial bodies with each other, which is obviously the result of the same law. It had been remarked in some few cases, that gases combine in simple proportions; for example, of equal volumes, or of two volumes of one with one volume of another. This last case had in particular been observed in the combination of the elements of water. This induced him to examine other combinations of this class of bodies, and his investigations led to the general conclusion, that bodies in the aerial form combine in ratios the most simple, those of 1 to 1, of 1 to 2, or of 1 to 3, &c. in volumes.

This view of the subject has one peculiarity. When the proportions of the elements of a compound are estimated by weight, there is no simple expressible proportion between them in the first combination. It is only when there is a second combination of the same elements, that the additional portion of one of them is a multiple of the first: but in elastic fluids, even in the first combination, the two elements have a certain simple proportion to each other.

Berzelius has generalized the view given by Gay-Lussac. Every body is convertible, or may be supposed convertible, into the gaseous state; and all bodies, he supposes, combine in simple proportions, estimated by volume, in the elastic form. Under this modification, it constitutes what he calls the theory of volumes.

Another relation still more important and more comprehensive was brought forward by Mr. Dalton. If it be admitted, that in the combination of two bodies in certain proportions, they unite atom with atom singly, or that they unite one atom with two atoms, with three, or with any number of atoms, then the relative weights of these atoms may be inferred from the relative quantities in which the bodies combine; for in the case where one body combines with another in one proportion only, and in which Mr.

Dalton assumes the combination to be that of one atom of the one with one atom of the other, the weight of the atoms of these bodies must be as the quantities in which they combine, since, by the assumption, these quantities respectively contain the same number of atoms. The elements of water, for example, oxygen and hydrogen, combine in the proportion by weight (p. 78) of 88.89 oxygen and 11.11 hydrogen, that is in the proportion of 8 to 1. The combination, it is supposed, consists of one atom of oxygen with one of hydrogen; the number of atoms of oxygen, therefore, in the quantity of it which enters into union, and the number of the atoms of hydrogen in the quantity of it which combines, are the same: hence the weight of an atom of oxygen must be to thet of an atom of hydrogen as 8 to 1.

The weights of the atoms of bodies, it is obvious, may be equally inferred from combinations of these in different proportions, if these are in simple arithmetical ratios to each other. Thus carbon forms a combination with oxygen in the proportion of 42.14 carbon to 57.86 oxygen nearly 5 per cent; or more accurately as 6 to 8. This is assumed to be what Mr. Dalton calls a binary combination, or that of one atom of the one body with one of the other: The weight therefore of an atom of carbon is to that of an atom of oxygen as 6 to 8. But those bodies combine also in the proportion of 27.23 carbon to 72.77 oxygen, that is in the proportion of 6 to 16. This is inferred to be a compound of an atom of carbon with two atoms of oxygen: It equally follows from it, therefore, that the weight of an atom of carbon is to that of an atom of oxygen as 6 is to 8.

In this system, altogether independent of the hypothesis of the weights of the atoms of bodies, is implied the *fact*, that one weight of a body, or a simple multiple of that weight, will always enter into its combinations in relation to certain uniform weights in which other bodies combine. The element hydrogen, for example, entering into combination as 1, the element oxygen will enter into combinations in a quantity as 8. or some simple multiple of it; carbon as 6; sulphur as 16: *that is*, the quantities in which these bodies enter into combination will all have the relation of these numbers, or of simple multiples of them to 1, denoting the quantity of hydrogen, and of course will have these relations to each other. It is this exposition of facts which it is of so much importance to trace, whatever opinion may be formed with regard to the hypothesis connected with it, or assumed to explain it.

It has been objected to the system of atomic weights that the admission of the facts does not necessarily lead to its adoption. It may be admitted that combination takes place between two bodies in certain fixed proportions, and that these have simple arithmetical ratios, the larger being a simple multiple of the smaller; but it does not thence follow that the first combination is that of atom with atom, and that the other proportions are those of one atom to two, three, or four. It is possible, that instead of attraction being exerted from atom to atom individually, a certain number of atoms of a body may exert the most powerful force, and enter into the combination it forms; and all that is strictly established is, that whatever number enter into the first combination, double of that number enter into the second, and three or four times the number into the third and fourth combinations.

The theory of atoms, it must be confessed, is hypothetical as relates to the supposition that the weights of the atoms of different bodies are to each other as are the weight of an aggregation of those atoms, when they form the constituents of a compound. But no hypothesis can be more natural, or better connect and account for the relations of compound bodies. Nor can any thing more decisively prove the correctness of the theory than this, that what is objectionable in it vanishes, by simply changing the word *atom*, to another, which, without being an alteration of the sense, is a more naked expression of the fact. It is the suggestion of the late Dr. John Murray.

He proposes to denote that quantity in which a body enters into combination, compared with other quantities in which other bodies combine, by the term *combining quantity*. This word will express the same thing (but without any hypothesis) as Mr. Dalton's weight of an atom, or as a volume in the hypothesis of Berzelius and Gay-Lussac. And whether it denotes the weight of a single particle, or of a certain number of particles which always go together, it is equally proper to express the fact.

Berthollet's idea that the acting bodies are divided among each other, in proportions depending upon their relative masses and attractions, has been combated and disproved by Pfaff, who has shown that tartrite of lime is completely decomposed, by adding to it a quantity of sulphuric acid, exactly sufficient to saturate the lime it contains; and in the same way he has shown that oxalate of lead is decomposed, by adding sulphuric acid sufficient to saturate the oxide of lead: In these cases pure tartaric and oxalic acids are evolved.

The doctrine of Berthollet is inconsistent with the important law, so well established "that the larger portion of one of the ingredients in a Chemical compound is a simple multiple of the smaller." Whenever powerful attractions operate, definite proportions are established, and the laws with regard to them observed; but where attractions are weak, combination is either unlimited, or if it take place in certain proportions, these are not so invariable but that others may be formed. In those cases we will find that the unions are more properly mixtures than combinations.

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